

BUILDING SUPERINTENDENCE FOR STEEL STRUCTURES

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BUILDING SUPERINTENDENCE FOR STEEL STRUCTURES

A PRACTICAL WORK ON THE DUTIES OF A BUILDING SUPERIN-
TENDENT FOR STEEL-FRAME BUILDINGS AND THE
PROPER METHODS OF HANDLING THE
MATERIALS AND CONSTRUCTION

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ILLUSTRATED

UNIV. OF
CALIFORNIA.

AMERICAN TECHNICAL SOCIETY
CHICAGO

1917

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INTRODUCTION

THE problems of superintendence of steel frame structures are so different from those which arise in connection with other types of buildings that it has been necessary for men to make a specialty of building superintendence for steel buildings. The knowledge of the best types of design, the proper methods of fabrication, the tests which should be conducted for quality of steel, and finally the proper methods of erecting the steel, all call for special training apart from the usual building superintendence methods.

¶ It is with the idea of giving engineer and layman the most authoritative information on this important subject that this little volume has been published. It does not attempt to go into the theory of design of steel structures, but confines itself to the problems of superintendence alone. The author is abundantly qualified to speak on this subject as he has erected many steel buildings for one of the biggest contracting firms in the country. He has given the reader the benefit of his experience as a superintendent by outlining the duties of this office, and making clear the engineering, legal, and practical knowledge required. Then he goes into detail regarding the inspection of the steel material in the fabrication shops and the proper method of storing it until needed. The problems of erection are all treated—equipment required, foundations, the handling of the steel, riveting, and painting.

¶ The author closes the article with some advice as to the proper organization of his force, how the superintendent should work with architect and owner and what qualities a good superintendent should possess. Altogether the article should prove a valuable addition to the technical literature in this field.



REPUBLIC BUILDING, CORNER STATE AND ADAMS STREETS, CHICAGO

Courtesy of Holabird and Roche, Architects, Chicago

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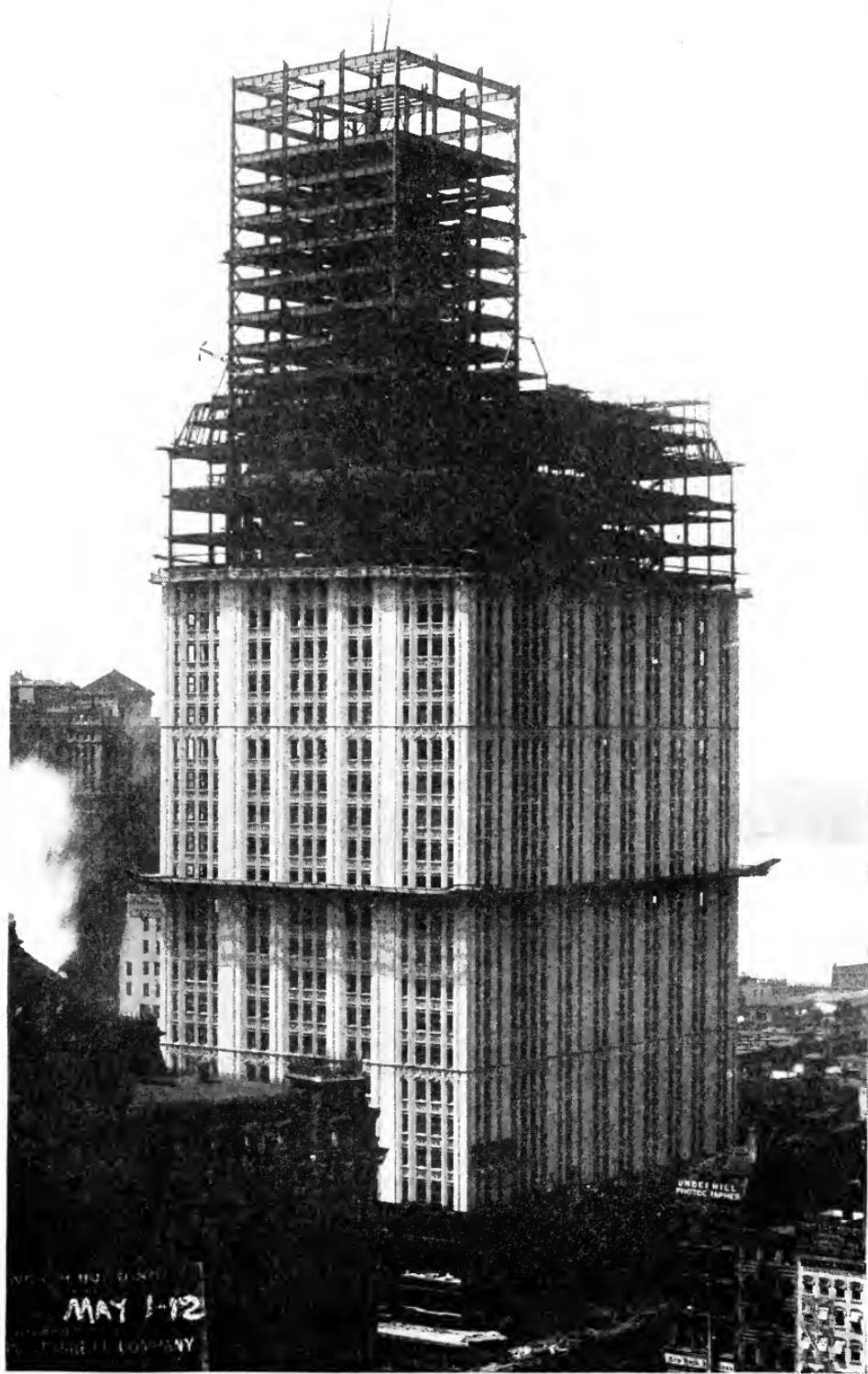
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WOOLWORTH BUILDING IN PROCESS OF CONSTRUCTION

Cass Gilbert, Architect

For other views see opposite foreword and page 349 of this volume

Courtesy of Thompson-Starrett Company, New York City

BUILDING SUPERINTENDENCE

STEEL CONSTRUCTION

INTRODUCTION

Classes of Structures. Steel structures are practically divided into two classes: first, those that are built as part of buildings; and, second, all those used for other purposes, such as bridges, viaducts, railroads, etc. Steel structures are now usually designed by engineers who have specialized in one of the two classes. The details of design and methods employed in the fabrication or in the manufacture of the parts of steel structures are somewhat different for the two classes.

Steel for bridges, etc., and in a limited way for buildings, has been used for a great number of years, but the modern practice of employing steel skeletons has been developed entirely since 1883, when the first structure of this kind was erected in Chicago, namely, the Home Insurance Building at the northeast corner of LaSalle and Adams streets.

Structural Steel. Manufacturing Processes. Steel, before it reaches the site of the structure ready for erection, goes through several different processes and stages of manufacture. First, the iron ore is smelted and made into pig iron; the pig iron is then converted into steel billets; these in turn are rolled into what are called structural shapes, such as plates, bars, angles, tees, channels, I-beams, etc., all of which is done at what is usually termed "the mill". The structural shapes are next taken to the fabrication shop where they are cut, punched, assembled, riveted, and bolted together, and otherwise manufactured according to the specifications, into the different parts of the structure, such as columns, girders, etc., and made complete so as to be easily erected at the site of the building.

Standard Sections. Certain methods of procedure and details of construction have been standardized for both classes of steel structures. The standards used in steel buildings are of recent

development and have been formed to meet the practical conditions encountered in the manufacture and erection of such work, principally to lower the cost and to facilitate the speed of completion. Radical departure from standards in the steelwork means delay and extra expense. A rolling mill with a large business in making standard stock shapes dislikes to stop its machinery to make special shapes, and does so only when paid handsomely for the extra trouble involved. Fabrication shops have expensive machinery built for standard work and organizations of men trained accordingly. It costs money and time to change the machinery and to educate the men to departure from the system of standards.

Good Design. Good designing of steel structures allows a maximum amount of assembling work to be accomplished at the shop, leaving a minimum amount to be done at the site of erection, depending always upon the limitations of transportation of materials from the shop to the site and upon those of the machinery available for use in the work of erection. Railroads are limited as to the size and weight of the pieces which they can handle, and it is better and more economical to employ machinery and equipment that can be used for several jobs, than that which is limited to one only. Therefore, the separate pieces of steel should come to the site in shapes and sizes adapted to standard erection equipment.

Divisions of Work. *General Divisions.* The duties of the engineer and of the architect divide themselves into what are called office work and field work. The office work consists briefly in making the design; in preparing the contract, drawings, specifications, and other papers; and in receiving the bids and awarding the contracts for the job.

The field work performed by an engineer or his subordinates is termed the superintendence of the work. It consists of inspection; examination; testings; and supervision, primarily to see that the work in the mill, the shop, and at the site conforms to the contract requirements. It also includes making reports of progress, etc., forming estimates of amounts due the contractors from time to time, and other duties chiefly of a business nature.

Superintendent. The engineer or his subordinate who undertakes to superintend the work of erecting a steel structure must have good health and steady nerves; he must also be a good climber,

because it is necessary for him to go to all kinds of places, sometimes at great heights, in order to give the work proper and adequate inspection. He must be a man of good judgment and he should never forget that he is part of an organization or machine whose object should be the completion of the structure in the shortest time, with the least confusion, and the smallest expenditure of money consistent with the result desired. The superintendent must remember that he is a cog in this machine. If the cog wants to go the wrong way, or if it does not fit into the other cogs, great loss of effort and sometimes great damage may be occasioned. His principal duty is to see that the work conforms to the contract requirements, and this must be done in a helpful way. A superintendent who does not know his business or who has a disagreeable disposition may so hamper the work and hinder the contractor as to delay the completion of the structure, and thus defeat the whole object of the operation. An owner primarily wants his structure erected according to the contract requirements, but he is also more than likely to want it completed as soon as possible. Often the entire success of the owner's plans is dependent upon the work being done in a short time; therefore the superintendent is not working in the interests of the owner if he, for any reason whatsoever, unnecessarily impedes it. He is also a poor manager if he allows inferior workmanship and materials to enter into the structure, or if he permits the contractors, or anyone else connected with the operation, to delay it unreasonably. In fact, he must do his own work properly, promptly, and at the right time, and must see that all others interested in the operation do the same. "All others interested" includes not only the contractors and the men under the superintendent but those over him as well. To be able to accomplish all that is demanded of him, a superintendent must be diplomatic, and, it goes without saying, must know the details of his business. We shall later discuss more at length some of the duties required of a superintendent.

Designing Engineer. The engineer who specializes in the design of bridges, etc., is usually supreme in authority in his realm of work and, because of the nature of these structures, he demands the greatest care and accuracy both in the manufacture of the parts and in their erection.

The engineer who designs the steelwork for buildings must make his work conform to the conditions imposed upon it by the design created by the architect, who is usually supreme in authority both as regards all matters of design and as regards the procedure at the building.

In modern practice, the work of the designing engineer and that of the fabricator and of erector of steel structures are entirely separate and distinct, the one designing, and the others contracting to manufacture and to erect the structure as designed. Sometimes the designer and the erector are employed by the fabricator, but though each of the three more often performs his share of the work separately, yet each is more or less dependent upon the work of the others.

The designer deals principally with the theoretical construction and the economical use of the materials entering into the work, so that the owner who employs him may have a structure to be used for certain purposes at a minimum expenditure of time and money.

The fabricator deals mostly with the economical use of shop machinery, methods, and the employment of workmen in the shop, all to the end of making the cost of the shop work as small as possible.

The erector is concerned with a similar problem at the site of the structure.

The designer, although he must necessarily know a great deal of the methods of shop practice and of those employed by erectors, does not dictate to the fabricator or to the erector altogether as to how the desired results are to be obtained. He does specify, however, certain processes which he wishes employed by the fabricator or erector and he should do so; for example, while he may desire that the rivets be driven by use of power riveters of given capacity, he allows the others to determine what make of riveter shall be used and what kind of power shall be employed—whether steam, air, electric, or other. Again, while conditions may require the designer to specify that the erector shall allow no smoke to be made at the site, he permits the latter to determine just how this result can best be obtained.

The designer should always be supreme [in authority as to the results desired. He should, however, take into consideration the limiting conditions of shop and erection, and the less he dictates to the fabricator and to the erector as to the methods to be employed

in obtaining the desired results, the more freedom he allows them in the use of machinery, equipment, and men available, thus enabling them to do the work at less cost to the owner. On the other hand, the designing engineer should not be too general in his specifications of requirements, because it is right and desirable that bidders for certain work should bid on essentially the same thing and that there should be no uncertainty as to the results desired. The specifications of the competent engineer must be a happy medium between those too exacting and those too general.

GENERAL SUPERINTENDENCE PROBLEMS

RECONCILING THEORY AND PRACTICE

Value of Forethought. Theoretically, a knowledge of the contract requirements and of the construction details, together with authority to reject all work that does not conform to them, is all that a superintendent needs in the way of equipment to make an expert. Practically, he needs much more.

Forethought is most important. It is proper to exercise authority to reject work, but it is far better to use forethought so that the work will need no rejection. It will be found that work once completed is not always as easily corrected as might be supposed. The best of men dislike to take down work already finished, and, when ordered to do so, often make great efforts to avoid doing it, thereby creating much confusion, delay, and dissatisfaction. If rejection of work becomes necessary, it must be done promptly and decisively; the matter must be followed up and the correction forced without delay. Much expensive alteration is often caused by lack of attention to defective work at the right time.

Judgment in Handling Mistakes. The superintendent must not be too lenient regarding mistakes, nor too credulous. On the other hand, he must not be too exacting. He must know what is right and act accordingly, with justice to all. A thorough knowledge of the practical side of the shop and field work gives him the assurance to decide correctly and to stand by his decision. Too much purely theoretical and too little practical knowledge often tends to make a superintendent severe and unjust. This has a tendency to work not only against the interests of the owner, his employer, but against his own as well.

Theories of Designing Engineer vs. Actualities of Contractor.

The office force of the engineer strives to create a design which will result in a structure as near theoretical perfection as it can be under the conditions imposed upon it. This force deals largely with the theory of design, the theory of strains and stresses, etc. The contractor has more largely to do with the actualities. The training of a contractor is different from that of the engineer. The former is likely to find out earlier in his career what can be done with the forces of nature, and what he may expect to happen if these forces are defied; therefore his knowledge is of a more positive character.

The superintendent soon learns that it is one thing to put down on paper something that it is desirable to execute and quite another thing to accomplish this result in the field. One important reason for this lies in the fact that the human element enters largely into the work after it leaves the engineer's office and that it is with this element that the superintendent must deal, to a great extent. The good superintendent must have the ability to manage men, to get them to do the right thing at the right time.

Problem of Handling Men. Inspection involves the intelligent examination of work and materials and a report as to whether or not these conform to specifications or to contract requirements, while superintendence includes not only inspection, acceptance, and rejection of work and materials, but also to some extent supervision of the work and the men. This supervision, however, must not encroach upon or interfere with the supervision which is the duty or the right of the contractor.

Characteristics of the Workmen. A superintendent of structural steel construction comes in contact in the field with the following men: the owner, the architect or the engineer, the contractors, the contractors' superintendents, the foremen, the sub-foremen, and the workmen who are called "structural steel men" or "bridgemen". The structural steel men, or bridgemen, are as a class, strong, plucky, and fearless, and they must necessarily be so. It requires steady nerves and strong muscles to enable a man to climb to dizzy heights, to lift heavy loads while there, with but little support, and to guide the heavy steel into place. These bridgemen are usually men of strong likes and dislikes. They are clannish and will take great risks and fight death itself to help each other or to help those they

like or respect. On the other hand, they will go a long way to cause discomfiture to anyone they may dislike. They are usually good and ready fighters, rough spoken, quick tempered, and used to danger; but when properly approached they are easy to handle. Most of these men are of a roving disposition, going from town to town and following the work. They are usually of a type who know their business thoroughly, or think they do, and dislike extremely to be ordered about. Consequently the contractor, his superintendent, and formen, must have tact, nerve, and physical strength, in order to control and guide these men successfully. It is part of the duty of the engineer or superintendent to study and understand the characteristics of all the men with whom he has to deal and to set them a good example.

Personal Relations. As in most practical business life, it will be found that success in the field work of the construction business is to a large extent a question of personal relationship. In order that the work may be carried on with the least amount of lost effort, the different persons connected with it must maintain their proper relationship one to the other, and they must "get along" together. The superintendent is in a position to do much toward preserving harmony and he should seize every opportunity to do so. He may quietly and diplomatically say a word now and then to ease or alter the feelings of the men toward one another.

While the superintendent must maintain a certain dignity, he must, nevertheless, be tactful enough not to consider it beneath him to be friendly with the men. He must realize that his job is an important one which cannot be slighted, but if he assumes the attitude that his specific knowledge is something sacred, only attainable by the favored few, he is likely to antagonize those with whom he works, who have not had his advantages. Such a mistaken position will surely cause him to lose much of his influence over the men. The latter usually know fairly well most of the things concerning the work which the superintendent knows; they have had these things taught them by hard knocks and generally form shrewd opinions as to the accuracy of the superintendent's knowledge. These practical men in the field are very likely to take advantage of any weakness of the superintendent and employ it to their own gain. Conceit is a dangerous weakness in a superintendent,

one which a shrewd contractor often makes use of to further his own interests.

A tactful superintendent insists, in a friendly but dignified way, upon the substantial fulfillment of the terms of the contract as they actually are and not as someone thinks they are. He also demonstrates that his presence is a factor that aids materially in keeping harmony, speed, and continual "push" in the work.

A good superintendent is not petty, but looks at things in a broad-minded way, with an appreciation of what is essential and what is nonessential. It is difficult to put down on paper the rules to follow or the methods to use in handling men. A man must learn these things largely by experience. One can get along best with some men by treating them kindly, with others by using strict discipline. Some men one must praise; others one may ridicule and banter. Some men need encouragement, while others are too cocksure. Each man is a separate problem and the more important the man, the more important is it that the problem should be solved correctly.

Progress Charts. The superintendent also soon learns that the most carefully formed plan of procedure, mapped out at the beginning of the work in the field, can seldom be followed very closely, for the reason that unforeseen conditions are continually arising at the site. A flood may carry away the falsework of part of the bridge; certain cars of material may be lost on the way to the site; the owner, when he sees the building actually begun, may change his mind, and often does, as to certain pre-arranged requirements, upsetting completely the carefully prepared theoretical progress chart.

Generally, it is the unexpected that happens. The capable builder successfully solves the problems from day to day as they arise, and is quick to act and to take advantage of opportunities for the sake of getting the entire job completed on or before a stated time. A good superintendent is a help to the builder in pointing out opportunities that may appear.

Shifting Character of Contractor's Organization. By the term "organization" we mean the combination of men, machinery, and equipment brought together to build a certain structure, and this suggests a difficult problem in construction work. It usually takes some time to create a good organization and, in work of this char-

acter, no sooner has a good one been established than the job is completed, after which there is no longer a need for that particular organization. Men have different capabilities and characteristics; some work well under one foreman while they cannot get along with another; a man operates one machine better than he does another, and so on.

Practically, the contractor cannot afford to keep a complete organization standing idle, and very seldom do the jobs come along in such sequence as to enable him to transfer his organization in its entirety from one job to another. He therefore loses his men; they obtain work with other contractors; and the next time they are wanted, they cannot be obtained. The superintendent must understand this element of practical work for the reason that, although the contractor may be capable and desirous of doing the right thing, he often has unknown men working for him, who do things contrary to his wishes and instructions. The superintendent must be able to detect this condition and have it corrected. He may find, if he is alert, many opportunities to save the contractor, as well as the owner, much annoyance and expense caused by the non-efficient, careless, and thoughtless workman. While the contractor is bound to correct the mistakes made by his employes, he will be grateful for timely information which will save him the expense of correction, and the prompt detection of errors furthers the advancement of the job, which is, of course, to the interest of the owner.

HANDLING BUSINESS DETAILS

Value of Business Methods with Business Men. It is essential that the superintendent should have knowledge of the business methods of the community in which he has to work. Scientific training generally is limited to a study of the laws of nature and their results. Business training teaches one how to deal with men and money and how to understand the laws relating thereto. The owner and the contractor are usually thorough business men, used to business methods, and they cannot work in harmony with those not similarly trained. Engineers and superintendents, to convince the business man of the importance of recommendations and decisions, must talk to him in terms which he can readily understand: that is, they must use the language of business.

Appointments. One of the fundamental rules of business is always to keep an appointment and to require others to do likewise. A strict observance of this rule will save much time and annoyance.

Daily Records. The superintendent should keep a daily record of the work under his supervision. This record is sometimes called the "log". It should state the condition of the weather each day; the approximate number of men employed on the different branches of the work and, briefly, what they are doing; the time when the different kinds and parts of the work were commenced and are to be completed; all unusual occurrences coming to the superintendent's notice, such as accidents, mishaps, delays, together with their causes; the visits to the work of prominent people connected with the operation. It must be accurate, complete, and clearly stated, so that anyone taking it up in the future, after these things have been forgotten, may have an adequate idea of what really happened at the time the log was made. A good attitude of mind when writing up the log is to assume that it will be needed in a lawsuit at some future time, the decision for which may rest upon the record contained therein. This log, however, must not be a "manufactured" one; that is, it must contain a statement of facts as they really happened, not as someone might wish they had happened.

Contractor's Payments. The engineer and the superintendent must know in a general way the values of the different branches of the work coming under their supervision; it is by means of their certificates that the contractor is paid by the owner, and these payments must be just, neither too large nor too small. The engineer and the superintendent must keep an accurate account of all payments that have been made and of those that are due to the different parties concerned.

Superintendent's Rulings. In making rulings or in rejecting work, the superintendent should take the matter up with the proper person in authority. It is not enough to give orders to the workmen; in fact, important ones should never be given directly to them. The dealings should be with the foreman, the contractor's superintendent, or with the contractor personally, depending upon the importance of the matter. It should be an iron-clad rule that all work which has been refused, or is liable to rejection, should immedi-

ately be called to the attention of the contractor himself or to the man next highest in authority who can be reached without delay.

Purchases. The engineer should know enough of the laws of business to be able to purchase materials and other things cheaply and without being imposed upon.

LEGAL POINTS ENCOUNTERED

Importance of Legal Knowledge. The engineer and the superintendent must recognize the existence of a rigid framework of legal principles upon and around which all the affairs of the business world are carried on. To refuse to acknowledge this or to act in a manner contrary to these principles is to invite disaster. The engineer finds that there are forces at work in the business world which he is compelled to meet, conquer, and use; and that they are almost as irresistible as the forces of nature with which he deals when designing the structure. It is easy to imagine what would happen to his work if the engineer, in designing it, should attempt to defy the law of gravity; it is not so easy to see what would happen to it if the laws of business were defied; yet the result is sometimes just as disastrous.

All business is at bottom principally a matter of contracts; therefore it is essential that the engineer and the superintendent should know something of the law relating to contracts, and also something of the law of agency.

In olden times, personal right was a question of might. As civilized life became more complex, the principal method of enforcing right was changed from might to the recognition of a system of rules regarding personal and property rights. These rules are now known as "the law". As the construction business becomes more complex, it is found that careful compliance with the law becomes more and more important.

Rudiments of Law. There are certain underlying principles recognized by all authorities that may be termed the rudiments of the law. Other principles are not so clearly stated or understood and therefore authorities differ regarding them. We emphasize the necessity and the importance of the engineer and the superintendent having a clear understanding of the rudiments of the laws of the community in which they work. The handling of the complex

problems and questions of law may need to be settled by an attorney, but the more the parties to an agreement understand and follow the rudiments of law, the less will they need the services of the attorney and incur the consequent delay and expense.

Field of Private Law. The engineer and the superintendent come in contact largely with that branch of the law known as private law or the law of contracts and the law of torts. Contracts are agreements of any nature. Torts are private wrongs not covered by contracts. Injury inflicted upon the property or body of one person by another, which injury is not a breach of contract, is a tort. Torts and crimes often overlap. Contract rights are obtained only by agreement. A tort, in distinction, has to do with one's natural rights, it is the violation of such rights, independent of contract.

An engineer or a superintendent will probably learn early in his career, sometimes to his discomfiture, that all agreements, or that certain provisions of a contract, even though they are a part of a written and signed document, may have no force in the courts, if either party should choose not to abide by the terms of the so-called agreement or contract. The reason for this is that such terms are not in accordance with the law of the community and will not be enforced by the courts.

Parties may enter into any kind of agreement they choose, if the provisions and conditions are legal. There are, however, what is known in law as "impossible contracts".

Contracts. A contract has been defined as "an agreement between two or more competent parties, enforceable in a court of law, and based upon a sufficient consideration to do or not to do a particular thing." The essentials of a contract are briefly: *first*, parties competent at law to make an agreement; *second*, something to agree upon; and *third*, a sufficient consideration for the bargain.

Other definitions of a contract have been stated as follows:

"A transaction in which each party comes under an obligation to the other and each reciprocally acquires a right to what is promised by the other."

"A convention by which one or more persons obligate themselves to one or more other persons, to give or to do, or not to do something."

Consideration. One of the important things required in a

contract is the consideration. If there is none named, or if it can be shown to the satisfaction of the court that the consideration named is not a proper one, the contract is not valid. It must be understood that consideration means compensation. There is, of course, the money consideration which is the most common one, but considerations at law are not limited to money. The theory of the law is that both sides of the contract shall, in the opinion of the contracting parties, be equivalent or equal in value.

Competency of Person Making Contract. Another thing required in a contract is that the person or persons making the agreement be competent at law, or be legally qualified to make it. In this connection the engineer most often takes care to see that persons binding or attempting to bind a corporation are authorized to do so. Generally, it will be found that only certain of the higher officials of a corporation, such as a president or a vice-president, has any proper or original authority to sign contracts for the corporation. The corporation does, however, have agents in varying capacities who can with authority bind it in a limited way. Another thing that must be looked out for, is to see that the signature attached to an agreement or other document, such as a receipt of payment, is complete. The name of the principal, that is, the corporation, person, partnership, or organization, for which the person may be signing, must be written first. Under this should be written the name of the person signing, and beneath this his title or office, such as agent, cashier, president, or whatever it may be. If a man should sign simply his own name followed by his title or office, he would not bind his principal but only himself personally. Again, the mere name of the corporation, partnership, or organization is not sufficient; it should be followed by the signature of an authorized officer or agent.

Relations of Partnerships and Corporations to Contract. Partnerships may be defined as the combining of two or more persons by agreement in an enterprise for common profit. The law pertaining to partnerships is different from that pertaining to corporations. A partnership may be created by mutual consent of the partners for the transaction of any kind of business which an individual has the right to transact, the only limitation being that the enterprise must be for a lawful purpose. In a partnership

each partner has the right to act as principal for the others, and each individual partner is liable for the acts of the other partners. Each may bind the other by contract. However, if the partnership has adopted a firm name, a contract made in the name of one of the individual members does not bind the partnership. It cannot be bound by any name other than its own.

A corporation must have permission from the government to do business. It cannot be formed for every purpose. An individual or a partnership can engage in certain lines of business which are denied to a corporation. A partnership no longer exists when one of its members dies or when a change in membership is made, while a corporation is not affected by the death of some of its members nor by any change of members, but has a continuous existence during the term for which it is created? As stated before, each partner is the recognized and authorized agent of the partnership, while in a corporation only those appointed in a manner prescribed by law and by the rules of the organization, can act as agents.

Subject Matter of Contracts. The subject matter of a contract must be a lawful one; any agreement to do an unlawful thing would make the contract null and void.

To know whether or not the subject matter or the statements in the contract are legal—in other words, whether or not the terms of the contract can be enforced in the courts—often requires a considerable knowledge of legal relationships and need not be discussed here except to mention briefly some of the more important things which are known to be illegal.

A contract cannot contain agreements which violate some state or federal statute, or which are contrary to the rules of what is known as common law, or which are forbidden by public policy. Statutes and the rules of common law are well defined, but the doctrines of public policy are somewhat elastic. It has been said: "Whenever any contract conflicts with the morals of the times and contravenes any of the established interests of society, it is void as against public policy". A United States Court has said, "Viewed from the standpoint of morals, square dealing, and commercial integrity," such and such a thing cannot be approved.

A few instances of general practice in the courts will aid one to grasp the general trend of the courts' interpretation of this matter

as related to construction contracts. The courts have held as illegal contracts which were plainly intended to obstruct justice, to encourage litigation, to restrain freedom of trade, to give excessive or highly arbitrary powers to an architect or an engineer, to bargain away the contractor's legal rights, or to tend to wrest from the courts their proper jurisdiction. An agreement that deprives the parties of their legal right to have their disputes and grievances heard by a properly conducted tribunal, such as a court of law, is held to be illegal, but an agreement which has arbitration clauses in it is held to be legal; in the latter case, if either party does not like the decision of the arbitrators, there are usually ways of taking the matter into the courts. Clauses that stipulate that the engineer or the architect shall have the sole power to fix the price of work that may be added, omitted, or altered from the contract work are generally held valid at law, and his decision will, in the absence of fraud or collusion, be enforced by the courts. The final word in case of dispute over the compensation can be given only by the courts. In some States it is held that clauses are void at law which provide that the architect or the engineer shall be the sole judge in deciding all matters in the contract, or that he shall be an arbitrator between owner and contractor.

Mutual Understanding. The agreement must be a mutual understanding between the parties. Usually it is held at law that, when a party signs his name to a written agreement, he admits the understanding of all the clauses, thereby making it a mutual one. It is essential, however, that there be a meeting of the minds of the contracting parties, for if there is a mutual mistake on their part, their minds do not meet and there is no contract. A mistake on the part of one of the parties only generally does not make the contract void.

Performance Prevented. If either party to a contract does or does not do something, and such act or failure to act prevents the other party from performing his agreements, the latter is excused from the performance of them.

Offers to Pay. An unconditional offer to pay in legal money, so as to stop interest and costs, is equivalent in law to payment. The law also declares what constitutes legal money. Private checks, silver certificates, and bank notes are not legal tender.

Breach of Contract. A breach of contract is the failure or refusal of one of the parties to a contract to carry out his part of the agreement. If one party notifies the other party that he will refuse to carry out the contract, the other party may stop the performance of his part of it, but he is entitled to and supposed to be able to collect the cost to him of work performed, and in some cases the profit that would be his if the entire contract had been completed. Profit, however, is not often a tangible thing, and its existence is often hard to prove in the courts. If one party refuses to perform his part of the contract, the other party cannot compel him to do so. The second party is, however, entitled to damages which are usually actual and rarely punitive, and can collect them.

One party to a contract cannot claim damages for breach of contract if the other party refuses or neglects to do some unimportant thing, unless the thing is clearly stated in the contract and is reasonable, because the law does not recognize trivial things. It recognizes substantial performance as actual.

Failure to Complete Contract on Time. In all construction contracts the time of completion should be agreed upon and clearly stated. It is usual also to include in the contract, at the time of making it, what the amount of the damages shall be if the work is not completed at the time mentioned. These damages must be named in the contract as "liquidated damages" and must be of a reasonable amount in order to have the courts enforce their collection.

Agency. Few business deals are completed or can be completed solely and personally by the parties to a contract; therefore the principals to a contract must have representatives or agents to help them. A corporation has no identity of a personal nature and of necessity performs all its acts through its officers and other agents. There are recognized rules and laws in all communities which govern the relationship existing between principals and their representatives, and which are known as the "laws of agency".

Appointment of Agents. Any person, corporation, or party, who has the legal right to enter into a contract, can appoint agents to act instead. Almost any one, except a very young child or a person who may have interests opposed to those of the principal, may act as an agent. The agent may be appointed in several

ways, in writing or orally. Any word or act of the principal which can be interpreted as representing the will of the principal, is sufficient. If one person asks another if he shall do something for him and the other responds with a nod of his head, this is held to be enough to make the first person an agent of the second to perform the particular thing mentioned. If a person does something unauthorized by another and the latter ratifies the act, then the first person becomes the agent of the second, at least in respect to that act.

Agent's Authority and Responsibility. If one man knows that a second is acting for him and permits the second to do things as his agent, the first one is liable for the acts of the agent just as if he had performed the acts himself. When it comes to the knowledge of a person that another is assuming to act as his agent, such person must elect without delay either to repudiate the acts of the alleged agent or else accept the responsibility for them.

A mere assertion on the part of a person that he has the authority necessary to act as the agent for another does not make him the agent, because only the principal's consent can make him so.

An agent cannot do for his principal anything which the principal cannot lawfully do for himself. While it is true that a third person dealing with an agent is required to ascertain at his peril whether or not the agent has actual authority to act for his principal, the third person has the right to assume that the agent has the authority to perform the duties which are customarily done by persons acting in the same or similar capacity, unless the principal should expressly call the attention of the third party to the contrary. For example, the duties of a superintendent are ordinarily understood to give him the power to do certain things for his employer and unless the employer openly states to the contrary (so as not to deceive the third person), then the third person has the right to assume that the particular superintendent with whom he is dealing has all the authority which it is customary for all superintendents to have.

When a third person, before dealing with the agent, ascertains that the agent has received authority of a certain character from the principal, then the third party may rely on the customary or apparent powers conferred and need not be apprehensive of unexpected or secret limitations upon such powers.

An agent cannot bind his principal beyond the limitations of authority conferred upon him by the principal, unless the limitations are of such a nature as to deceive a third party.

An agent can be held personally responsible at law for all the wrongful acts which he may commit; it is no excuse that he was acting as the agent for someone else.

An agent cannot, ordinarily, without the expressed consent of his principal, transfer to another his authority to act. However, where mere mechanical or clerical work is to be done, the agent can employ others to help him.

Liability Law. It is well that a superintendent know something of the laws governing liability for injury received on the work. It has been said that a principal, or master, is obliged to furnish his agent or servant with a reasonably safe place in which to work, and with reasonably safe tools and instruments. If the principal fails to do these things and the servant is injured through no negligence or carelessness on his part, what is known at law as a tort has happened and the principal is liable to the servant in damages for any injuries. The agent or servant must, however, assume the risks which naturally belong to the work in which he is engaged. If a workman carelessly steps off a scaffold he cannot collect damages from the contractor, but if the scaffold should be constructed in such a manner as to be unsafe and, falling, should injure the workman, then the latter can collect damages.

In most localities there are laws, such as factory laws, workmen's compensation laws, and the like, which govern what a contractor shall or shall not do toward insuring the safety of his men and of the public. The superintendent should make it his business to study these laws and to see that they are substantially obeyed.

Building Laws. Most communities also have regulations called building laws which govern the erection of all kinds of structures. Obviously the superintendent should be familiar with these laws. He should obtain copies from local authorities and study them carefully.

Lien Laws. These laws vary in the different States. They provide that in case a workman employed on the job, or anyone furnishing materials used in it, is not paid for his work or for the materials, he shall have the right by law to place a lien on the property, provided this is done in the prescribed way and within a given

time after the money is due. If the claim covered by the lien is proved to be correct, then the owner of the property will be compelled to pay the workman or material man the amount of the lien, notwithstanding the fact that he has already paid the contractor for this same work or materials.

It is important, therefore, that the superintendent study the lien laws of the State in which he works, and satisfy himself before issuing certificates for payment that the owner is protected against liens of all sorts.

Application of the Law. Complex Questions. The foregoing statements are only a few of the rudiments of the law. In applying them to the work, the superintendent should use common sense, always referring the more complicated points of law to the attorneys. The good sense of the engineer or superintendent will often be shown by referring a really doubtful question of law to an attorney instead of attempting to pass upon it himself. A certain amount of legal knowledge is necessary that the superintendent may know the proper relationship of things and the rights of all parties concerned; also that he may know what the terms of a contract and specifications really mean, in other words, that he may interpret them correctly. The use of common sense in these matters usually does more for the job than does the technical enforcement of laws. Substantial justice to all parties should be the object sought.

What the Law Expects of Superintendents. The law requires that an engineer, architect, or superintendent, who agrees to direct the work, shall be on the job a sufficient part of the time to enable him to give it prompt and adequate inspection. This means that he must, of course, know defective work when he sees it and that he will discover and examine it before it is hidden. When defective work is discovered or in any way called to his attention, the superintendent must without delay take action to effect its correction. If he is to reject any work he must do so promptly, for he has no right under any circumstances to conceal his discovery and then reject the work after much time has elapsed. Sometimes, however, the contractor or his men intentionally conceal defective work in an attempt to deceive. The superintendent must try to make such a contractor or workman see that it is not to his own interest to do that kind of work.

DUTIES REGARDING DRAWINGS

Draftsmanship and Superintendence Compared. Both the draftsman and the superintendent must have a technical knowledge of the work. The draftsman's work is largely accomplished by knowing how to make a good drawing; that is, he records his ideas and those of others in a concise, clear, and intelligent manner by making a series of lines and letters on paper. The superintendent, however, performs his task, for the most part, by handling the men. His conceptions and those of others are recorded in lasting steel or similar materials and not merely on paper. The draftsman personally makes the lines on the paper. The superintendent must compel others to make the record. It cannot be emphasized too strongly that it is just as important for the superintendent to know how to deal with men as it is for the draftsman to know how to draw.

Knowledge of Drawings Important. The more a superintendent knows about drawings and how they are made, the better. It is a duty for him to interpret the meanings of the different drawings, specifications, and other contract papers. In fact, he should know better than anyone on the job what the contract provisions are and this before the work is executed in the structure. If anyone has actually had a hand in making anything, the better will he be able to understand the process of its manufacture. It, therefore, is needless to say that the more experience the superintendent has had in the drafting-room, the better grounded he is in the abbreviations and conventional signs that are standard practice in the making of drawings, and, hence the more practical is his knowledge of the real intent of the drawings.

One who has perfected himself in the reading of drawings finds in the rush of work and in the noise and confusion, that this helps him to avoid mistakes, and gives him more time to devote to watching the progress of the work.

While it is possible for one who has never had experience in the actual making of drawings to perform successfully the duties of a superintendent, he is able to perform his duties better and more easily if he has had such experience.

Study of Drawings. It should be the duty of the superintendent, when he first gets the contract drawings and specifications, to read, study, and examine them thoroughly until he knows the

job from bottom to top. He should especially note unusual requirements, and those that are peculiar to this particular piece of work. He must not, however, depend entirely upon this first study; from time to time he must refresh his memory, especially of particular parts of the structure as they are about to be erected, so that he may have a correct and positive knowledge of the work as it is done. To illustrate: We are assigned to a twenty-story office building. Supplied with the drawings and specifications, we begin at once to study and ponder over them, and to ask our superiors about certain points that may not be quite clear, until we have an excellent idea as to what the contract includes. The actual work on the structure begins. While the foundation work is going on, it is not necessary for us to give the roof drawings any special attention; but a short time before the roof is reached, we should devote some time to studying again the drawings for this part of the work.

A man can undoubtedly do more work and better work by using some system and not by trying to retain too much in his mind at one time. The less the brain is occupied with the non-essential things, the more it can occupy itself with the essential.

Accuracy of Drawings. It is presumed, when the drawings and specifications are turned over to the job, that they are complete and accurate, but the superintendent should not take this too much for granted. He should be on the lookout for errors and omissions and correct them before they affect the progress of the work.

Supplying Workmen with Drawings. The superintendent must see that the different workmen are supplied with a sufficient number of copies of the drawings. A squad of men putting steel together on the twentieth story are very likely to go wrong in the work if the erection drawings are kept in the office on the first floor. The drawings must be located so that the workmen actually doing the work can refer to them continually and easily.

Handling Drawings. The particular drawing needed by the men may be tacked to a light drawing board which can easily be taken from place to place. This method preserves the drawings, saves the foreman time in handling it, allows the checking of the different pieces as the work progresses, and prevents the drawing from being blown away—an important consideration when the work is on a high structure.

Classes of Drawings. Two classes of drawings are usually made and supplied for the work in the field, namely, general and detailed drawings.

General Drawings. The general drawings are called by different names, such as assembly, framing, or setting diagrams. Each drawing is supposed to show as much of the structure as it can clearly, with the different parts assembled in the same relation to one another that they will bear in the structure. These drawings are usually on a comparatively small scale and constitute the plans, elevations, and sections of the building. They are in the nature of diagrams, which usually do not attempt to show the details of the connections of the different members, but rather to indicate the proper relationship of the members. The members are usually shown by a single line designated by some distinctive mark.

Marking System Necessary. It is very important that each piece that goes into the structure should be indicated in some simple manner on these general drawings by a mark that is different from those on all the other pieces.

There are several good systems of marking. An example of one sometimes used is as follows: Each piece of steel that belongs on a certain floor has a mark, the first character of which is a figure corresponding to the number of that particular floor; after this figure is a letter designating whether the piece is a beam, a girder, a separator, etc.; then follow other figures in numerical order given in some systematic way up and down or across the drawing; each piece that goes into a structure is given, at the shop where it is fabricated, the same mark as the one shown on these general drawings or setting diagrams. By this system, when a piece of steel is received at the building, marked "2B30", the erection gang knows immediately that this piece is beam 30 for the second floor; if marked "5G18", it is understood that it is girder 18 for the fifth floor, and so on. The last numbers of the marks having been placed on the drawing in some regular order, the squad boss, or person interested, can turn almost directly to the place on the drawing which shows where the piece is to go.

It is understood that the fabricator usually sends the work through his shop in such rotation as best suits his shop system,

and often ships together pieces belonging to radically different parts of the structure. For instance, if there should happen to be beams of the same size and of exactly the same detail located on all the floors from the basement to the roof, one can readily see that it would be cheaper to run them all through together, and to ship them at once so as to save the space in the shop.

Unless the erector has used some forethought and provided in the contract for the sequence in which the steel is to come to the job, he is likely to find that the fabricator cares very little how much sorting is required at the site. It is for this reason and for others of equal importance that some good and intelligent system of marking should be devised and used on the work; otherwise there is bound to be a great loss of time, which is equivalent to a loss of money.

Bridgemen are highly paid, and one can readily see the loss incurred, if, while workmen stand around idle, the boss of the gang has to make long search through a number of large-sized drawings, in order to tell where each little piece belongs.

Shop Detail Drawings. Shop details are drawings of each individual piece on a scale large enough to show without confusion all the information required to fabricate and erect this particular piece. These details give the men in the shop the exact knowledge needed to lay out, cut, punch, assemble, and rivet the piece shown, as well as to give it the proper erection mark. It is just as important that the men erecting the structure shall have a sufficient number of copies of the shop details on the erection work as it is for them to have the general drawings.

Conflict in Requirements. Sometimes there is a conflict between the requirements as stated on the drawings and specifications, and the formal contract. The contract is usually considered the most important paper because it is usually more carefully drawn than the others; the specifications are next in order, inasmuch as the person who writes them has more authority than the draftsman; the drawings are of least weight. It is, therefore, customary to rule that the specifications have precedence over the drawings. It is well, however, to know that the courts do not always uphold this practice, because they make the *real intent* of the agreement, no matter how it is shown, the primary consideration.

INSPECTION OF MATERIAL AND ERECTION OF STEEL WORK

Classes of Inspections. The three kinds of inspection, so called, that are given to the materials and workmanship of a steel structure are the "mill", the "shop", and the "erection".

It is not customary for the same man to make all of the inspections, one reason being that each inspection requires a somewhat different sort of knowledge. Another reason is that by having one man inspect a number of jobs at the mill, a second man inspect a number at the shop, and a third man inspect the erection, a great saving of time and money is effected, particularly in the matter of transportation.

There are now large corporations, as well as smaller concerns, who make inspection of all kinds their sole business. These concerns are able to do this at a reasonable price because they place men in the different large mills and shops and keep them there all the time. These men become very familiar with the workings of the particular institution to which they are assigned; consequently they know where to station themselves to do the most efficient work. They can watch a number of jobs just as easily as they can watch one.

MILL INSPECTION

Knowledge Necessary for Mill Inspector. The mill inspector should have a knowledge of metallurgy, particularly in its application to iron; he should also have a knowledge of chemistry and physics, inasmuch as his work deals largely with the composition and strength of materials. The materials entering into the work commonly termed steel structures, are cast iron, wrought iron, and steel. Each material has several grades. All differ from one another, chiefly in the amount of carbon they contain, but also in the quantities of other substances generally considered impurities, such as phosphorus, sulphur, manganese, and silicon. Wrought iron comes the nearest to being pure iron; it sometimes contains no carbon, and seldom over one-fourth of one per cent. Cast iron contains the most carbon, sometimes as much as five per cent; while steel has a chemical composition intermediate between wrought iron and cast iron.

Cast Iron. There are two principal kinds of cast iron—the gray and the white. These may be produced from the same ore by varying the conditions of temperature, gray iron by slow cooling, and white iron by rapid cooling. Gray iron should be used where strength is needed. It is soft and tough, melts at a lower heat than the white; remains fluid a long time; can be planed, turned, and drilled; is red when molten; and makes good castings. The fracture is granular, of a gray color, and has a metallic luster. White iron should be used where hardness is required. It is hard and brittle; is not easily melted; thickens rapidly; cannot be worked; and is white when fluid. The fracture is white in color, crystalline, with a vitreous luster.

Defects in Castings. The principal defects in castings are blowholes; honeycomb caused by confined-air cavities; flaws caused by the collection of foundry dirt and other impurities, and by unequal contraction while cooling; uneven thickness caused by the displacement of the cores; and cold-shuts, or weak seams, caused by the chilling of the iron where the molten metal is poured from different ends of the casting. The mold so chills the iron that it does not properly mix and unite when it comes together in the mold. Castings should remain in the mold until cold; the slower the cooling the better, for irregular and too rapid cooling seriously injures castings, particularly where different thicknesses of metal occur, by causing strains that often result in rupture under a small load.

Inspection of Castings. The inspector can test castings roughly by the use of a hammer. Honeycomb, blowholes, sand holes, etc., cause a dullness in the sound when the casting is struck. Gray and white cast iron can often be distinguished by the blow of a hammer on the edge of the casting. The one is soft enough to be slightly indented, while the other, being hard and brittle, chips off. In order that the flaws, shrinkage cracks, and blowholes may be detected, all castings should be inspected carefully when they first come out of the molding sand—after they have been thoroughly cleaned with steel brushes or in some other way but before they are painted and “doctored up”.

In long castings, or where calipers cannot be used, small holes should be drilled into the different sides so that tests of the thickness of the metal may be made. All castings should be tested for true-

ness of shape and dimensions. They should have a clear smooth surface with regular faces and sharp angles. The texture of the iron should show even and close grained when broken; the color should be a light bluish gray; and the fracture should have considerable metallic luster. Both texture and color should be uniform. If the fracture should show crystalline patches, or should be mottled either with dark or light iron, the casting may be unsafe; blowholes will make it still more unsafe.

Tests of Castings. In important work, where it is essential that the castings should have a given and uniform strength, tests are made. Test bars are poured before and after the castings are made, at least one for each two thousand pounds of castings, or in such manner as the specifications demand. These bars are usually made 1 inch by 3 inches by either 14 or 26 inches. They are placed narrow side up on supports either 12 or 24 inches apart, and are loaded in the center until they break, record being kept of the deflection and breaking weight. The bars that are to be tested for tensile strength are turned down by a machine to a given accurate diameter and then pulled apart in a testing machine.

Wrought Iron. Wrought iron, when perfect, is simply pure iron without carbon or impurities of any sort. It has a property which neither cast iron nor steel has—it can be welded in the old-fashioned way. That is, if two pieces are firmly pressed or hammered together when nearly at white heat, they adhere and make one piece. Cast iron and steel can now be welded by submitting them to certain recently discovered processes, such as the oxy-acetylene process.

Qualities. Good iron is ductile, tough, and fibrous, free from flaws, blisters, cinder pockets, buckles, and cracks along the edges. It is readily heated, soft under the hammer, and throws out few sparks. When broken gradually, it shows long silky fibers of leaden-gray color which twist and stick together before breaking. When broken rapidly, it has a crystalline appearance in the fracture.

Wrought iron which is brittle when cold or which cracks when bent double, contains phosphorus. This is called "cold-short" iron and is indicated, when broken, either by a coarse grain with discolored spots, or by a fine grain of steely appearance. Wrought iron which cracks when bent at a red heat but has considerable

tenacity when cold, contains sulphur, copper, arsenic, and other impurities and is known as "red-short" iron. Cracks on the edges of the bar are indications of red-short iron. Good wrought iron does not crack when bent 180 degrees around a bar with a diameter twice the thickness of the piece, or, when heated to a working temperature, it is bent sharply to a right angle. When cut slightly on one side and then bent, the fracture is nearly all fibrous.

Wrought iron which is not rolled or hammered after it has been brought to a white heat is injured. When the hot iron is suddenly cooled in water, it hardens and, if the load is gradually applied, the breaking strength increases, but the iron is more likely to snap suddenly without warning. When the metal is allowed to cool gradually, it softens and the breaking strength is reduced.

Rivets are usually made of soft, tough wrought iron, or of good soft steel, neither of which should crack when bent cold until the sides come together.

Tests of Wrought Iron. In the mill inspection of wrought iron, all tests are made after the rolling process, for, on account of the way this material is manufactured, accurate tests cannot be made before.

Tests for tensile strength, ductility, and elasticity are made by placing test bars, cut from the full-sized bar, in the testing machines, and recording the different weights observed. These test pieces are usually made 1 inch wide, by the thickness of the piece from which it is taken, by about 18 inches long.

Steel. Steel can usually be determined or distinguished from wrought or cast iron by the property of temper which it possesses, although the soft steels do not take a temper. When steel is suddenly cooled after being heated to a high temperature, it hardens and the degree of hardness or softness can be accurately regulated by the degree of temperature to which the steel has been heated. This is called giving it a temper.

Another method of determining steel is by the nitric-acid test. A drop of the acid produces on steel a dark gray stain.

Varieties of Steel. Steel is made by many processes, either by adding carbon to wrought iron or by removing a portion of the carbon in pig iron. Those most commonly employed in making steel for structural purposes are the Bessemer and open-hearth processes, the latter being the one now most generally used.

In the acid process the lining of the converter or of the hearth is of a siliceous material, such as limestone or quartz. In the basic process, the lining is made of calcined dolomite containing lime and magnesia, or some refractory substance which contains practically no silica.

Besides the varieties of steel given there are those known as puddled, blister, shear, and natural steel.

The three different grades of steel commonly spoken of are *mild* or *soft*, *medium*, and *hard*. Steels with less than 15 per cent carbon are soft; with from 15 per cent to 30 per cent carbon are medium; with more than 30 per cent carbon are hard.

For boiler plates and rivets, or where high ductility is desired, soft steels are used. For general structural purposes the mild steels are also used, while for axles, shafts, tools, and good wearing surfaces, the hard steels are preferred. When greater hardness and tenacity is desired, steel alloys are made by adding to the molten steel, small quantities of some metal such as nickel, manganese, chromium, or tungsten. These steel alloys are not commonly used in structural work.

When the metal is taken from the Bessemer converter, or from the open-hearth, it is run into ladles and poured into molds of uniform and specific sizes, usually holding more than 15,000 pounds of metal, termed ingot molds. As the steel comes from the molds in the form of ingots, it is rolled into the different shapes used in the trade, such as plates, bars, angles, channels, and **I**-beams.

Inspection of Steel. The mill inspector's work at a steel mill is largely confined to the examination and testing of the ingots.

The following defects are likely to be encountered in the inspection of ingots: segregation, which means the gathering together by themselves during the cooling of the ingot, of certain constituents, such as carbon, phosphorus, sulphur, and sometimes manganese and silica; cracks, both internal and external, caused by too rapid cooling; blowholes, caused by gas escaping during the cooling; pipes or cavities of conical shape, usually in the top of the ingot and caused by the outside cooling more rapidly than the inside. The ingot should be a solid mass of metal of regular shape when it reaches the rolls, in order that seams, laminations, laps that do not weld, cracks, pits, and other defects may not occur in the finished

rolled steel. Ingots should, therefore, be bottom cast and not disturbed until the metal has become solid enough to be moved without disturbing it. Ingots in which some of the metal has run from the mold so as to leave a cavity—bled ingots—should be rejected.

After a man has had considerable experience, he can judge somewhat of the quality and grade of steel by the appearance of the fracture; as the fracture, however, may be affected by the manner in which it is made, this test is usually found to be uncertain.

The quality and grade of the ingot steel is determined by testing samples of each heat or blow, obtained by running a small quantity of the molten metal into molds usually about 4 inches square, and afterward rolling them down to $\frac{3}{4}$ inch round; also by taking drillings directly from one of the ingots. These samples are usually tested for chemical analysis, for elastic limit, and for ultimate strength.

Marking and Recording. It is essential that each ingot tested should be clearly marked in some permanent way, either by stamps or by painting, so that the bar itself and the shapes it subsequently assumes can be readily and accurately identified at any time.

A complete record of each furnace, or converter full of melted steel should be kept, stating the character of the raw materials that went into the melt, the size and number of ingots produced, the number rejected, and the reason for their rejection.

Inspection of Rolling. The inspector of the rolled steel should watch for any defects which prevent the rolled shape from being a solid, uniform mass of steel, without cracks, seams, laminations, pits, cavities of any sort, or any other fault that will injure its strength and durability. The shapes should also be inspected for the proper size and dimensions, and for the straightness and trueness of the different pieces.

Tests of Rolled Steel. The inspector should select certain places in the rolled steel where test pieces shall be cut, properly mark them, and keep a record of the places. The testing of the samples is done usually in accordance with the engineer's specifications, which often direct minutely how the tests shall be made. The more common tests are the tensile, bending (both hot and cold), drifting (where holes punched a certain distance from the edge

of the piece are enlarged by driving drift pins of a certain size through them, and the result noted), welding, forging, hardening, and acid (where the material is placed in dilute sulphuric or nitric acid for a certain period, and, upon removal, its appearance noted). In making these tests, all materials not conforming to the specified requirements should be rejected.

Steel Specifications. It is needless to say that the engineer, in preparing his specifications, should be very careful with regard to the qualities and characteristics of the materials he demands and the tests they should stand. Usually, consultation with practical manufacturers of steel is necessary, in order to get desired results. The specifications should be consistent. Unless the engineer is an expert steel-maker, he should not attempt to specify both the exact chemical formula and the physical requirements, for by so doing he may demand that which cannot be obtained in one piece of steel. He should, however, fix certain limits, liberal rather than rigid, beyond which the hurtful elements should not go.

Necessity of Mill Inspection. Except in the more important work, where the engineer in his design has utilized his materials up to a high limit, and a uniform given strength is of the utmost importance, mill inspection may not be required. It will be found that commercial grades of materials of known uniformity can now be purchased from several different reputable makers and furnished in prompt deliveries, thus making it unnecessary to delay the work by insisting on the mill inspection. It is enough to bind the manufacturer to stand back of the materials he furnishes.

SHOP INSPECTION

Amount of Inspection Varies with Work. As in other things, it is well for the work and for the inspector if the fabrication is given into the hands of shops which are properly equipped with machinery, men, and management, and capable of performing the class of work desired.

The degree of accuracy of the shop work and the rigidity of inspection should be governed by the character and the nature of the structure into which the finished work is to go. For bridges, especially heavy bridges of long spans, and other structures where the engineer of necessity has strained the materials to the limit,

very careful work must be specified and required. For other structures, such as buildings where a greater factor of safety is used in the design, or where the failure of one piece will not necessarily jeopardize the entire structure, less exactness can be required. It is needless to say that the more exacting the requirements, the greater is the cost of the shop work.

The specified requirements and the inspection should be practical and not too theoretical; they should be made commensurate with the amount of money that the owner wants to and ought to spend for work of the character ordinarily furnished for similar structures.

Drawings in Shop. One of the first duties of the shop inspector is to see that detail drawings which have the approval and signature of the designing engineer are being followed. Sometimes the shops make their own details and it is important that these have the signature of approval. The inspector should be supplied with a complete set of these drawings together with a copy of the specifications and a bill of materials. He should have also a private place where he can keep these papers for his own use. If the specifications call for mill inspection, the shop inspector should be supplied promptly with a copy of the mill inspection notes, and he should see that all materials coming to the shop to be used on his work have been inspected and passed by the mill inspector.

Shop Processes. The various processes through which the materials are passed in the shop will now be considered somewhat in detail.

First Straightening of Materials. The steel and wrought-iron plates, bars, and other structural shapes coming to the shop from the rolling mill are carefully straightened and made true to shape by passing the materials through straightening rolls and other machines of different types. It is a matter of great moment to see that the work is properly done, because upon this depends the right distribution of the stresses for the different portions of the completed built-up members. Generally, the shop officials recognize the importance of having the materials straight and true, because they know that work performed in this operation is more than offset by the saving in labor and time in the assembling of the different pieces in the built-up member.

Marking. The next process is the marking off of the material. This is usually done by clamping to the steel, wooden templates prepared by template makers, and marking the steel according to the templates. Cuts are marked with a sharp hard instrument, and holes to be punched or drilled are indicated by center punches.

Punching. The next process is the punching. It is important that the machines, the punches, and the dies be of proper size and design, and that the edges be sharp and unbroken; otherwise, cracked and ragged holes will occur which should not be tolerated under any circumstances. The diameter of the die should never be more than $\frac{1}{16}$ inch larger than the diameter of the punch.

Second Straightening. After the punching is completed, the materials should again be straightened and trued up, because the process of punching causes more or less buckling. If not straightened, the several pieces to be riveted cannot be properly brought together and fitted, and often there will be enough spring between them to distort the rivets, so that many will be found loose when cooled.

Assembling. The next process is an important one. It is the assembling of the various separate pieces to form the built-up members, the pieces being held together temporarily by means of holding or assembling bolts. The inspector must insist there shall be a sufficient number of bolts to hold the work properly while it is being riveted; oftentimes the lack of a few assembling bolts causes a serious defect in the built-up member. The inspector should also watch to see that the several pieces are put together properly; that right-hand members are not put where left-hand ones belong; that certain pieces are not turned end for end; and that other mistakes of the kind do not occur. All surfaces riveted together which cannot be painted after riveting should be painted before they are assembled.

Reaming. When the holes are to be reamed, they should be punched somewhat smaller than the size of the finished hole. Punching tends to distress the metal on the edge of the hole, and thereby impairs the strength of the member to a greater or less degree. The extent of this distressed material varies with the thickness of the metal punched and with the size of the punch used. Reaming is the removal of this distressed material by the use of a sharp

rotary tool called a reamer. It is sometimes omitted in unimportant work, nor is it frequently done in building work except in column splices and at important connections, but it is almost always specified for all holes in bridge and railroad work. If desired, it should be definitely specified. Reaming can be done in the separate pieces before assembling; it is better, however, to do it after assembling, for then the holes in the different pieces are sure to correspond exactly and are "fair" for riveting, a most desirable thing. In fact, where reaming is not particularly mentioned, and where punched holes are supposed to come together accurately but do not do so, the inspector should insist that a reamer be used to correct the error. When this is done, a larger-sized rivet than the one specified will be required properly to fill the enlarged hole. The finished hole should be about $\frac{1}{16}$ inch larger than the diameter of the rivet specified. Reaming, of course, improves the work, but adds some to its cost.

Drifting. The shop men generally make a good deal of use of the driftpin, which is a cigar-shaped hardened-steel pin, used to make the holes in the different pieces come together in the assembling process, and to make the holes "fair" or true for the rivet. This latter process should never be permitted except in the cheapest kind of work or in unimportant places. Drifting distorts the material and in good work is never allowed after the assembled pieces are bolted up and some of the rivets have been driven. In fact, it is sometimes dangerous to allow it, because of the unequal strains it produces in the different pieces of the member.

Many first-class shops use the reamer without being told, as they find that the extra cost in so doing is offset by the saving in the cost of riveting. With perfectly true holes, the riveting goes much faster than otherwise. All burrs should be removed from the edge of holes before the riveting is done.

Riveting. After the reaming comes the riveting. In addition to seeing that the rivets are made of good material, there are two things which are essential in good riveting—the rivets should be properly heated, and they should be properly driven. The heating must be especially watched, because after the rivet has been driven there is no way of telling whether or not it has been burned. The head may look as it should, while the shank may be much injured and weakened. The heating forge should be placed conveniently

near the work. The rivets should be heated uniformly to a dull red heat, never beyond the orange color, as burned rivets are brittle and much impaired in strength. Nor should rivets be driven if they are not heated to the red color, for then they do not always fill the hole and the rivet metal is injured. Steel rivets require more watching than wrought-iron rivets, to see that overheating and underheating do not occur. They should be driven just as rapidly as can be, after they have reached the proper heat. If too many are placed in the forge at one time, they are likely to become overheated and spoiled.

Power riveting machines are used almost exclusively nowadays for driving the heated rivets. The pressure required to fill the holes properly is from 50 to 150 tons to the square inch of rivet section.

Loose Rivets. It is important that the right length of rivet be selected for each hole. The rivet must completely fill the hole, that is, the heads must be concentric, and fit absolutely tight all around. The riveting machine should make no marks in the metal of the heads, and the heads, when finished, should also be without cracks.

All loose rivets or those loosely driven should be rejected absolutely, and fresh ones driven into the holes. The defective ones can be detected by hitting a sharp blow on each side of the head with an inspector's hammer. This is a special tool, weighing one pound or less, with a handle quite small at the shank, to absorb at this point some of the spring of the hammer. Practice soon enables the inspector to tell the loose rivets by the action of the hammer. Sometimes they are made to appear tight by the use, after they are cold, of a calking iron, but the marks of the iron can generally be detected. The more modern way of concealing loose rivets is by squeezing the cold heads with a smaller die, or by striking the cold heads on the sides with the riveting machine. These last two methods are not so easily detected after the men are through with the work. Re-driving cold rivets by any method, and calking rivet heads, should not be permitted.

Rejecting Rivets. When the inspector rejects a rivet, he should mark it by striking it a blow with the stamping end of his hammer or by some punch. He should also mark the metal close to the rivet in the same way so that the new rivet can easily be

found and inspected. After this, a ring of chalk or of paint should be made around the rivet so that the shop men will not overlook the rejections. It is important that the different pieces to be riveted together shall be securely and snugly held by a sufficient number of temporary bolts before the riveting is started.

As in other things, an inspector can go to extremes in the testing of rivets and thereby do more harm often than real good. In the best shops, where high-powered machines and modern rivet-heating furnaces are used, there will be comparatively few rivets driven that really need to be rejected. The inspector soon learns where to draw the line. The importance of the structure should govern somewhat the exactness required. In large bridges and railroad work, the riveting should be nearer to perfection than in building work, although a good job should always be required on columns going into a building or any other structure. While poor workmanship should never be accepted, there are degrees of good workmanship. In a bridge the engineer depends almost entirely upon the different members to resist the loads, and he must of necessity strain his materials to a high limit. A failure of one connection in a bridge is likely to cause the collapse of the entire structure, but in a building such a failure merely causes a local injury and does not essentially damage the structure as a whole. It will be readily recognized that in a building some members are of more importance than others; particularly is this the case with the columns, because if one column near the foundation were to give way, great harm would be done; the collapse of a floor beam, however, is not likely to result in any great damage. In a building other materials are used in the construction which help the steel but which the designing engineer usually ignores in determining the size of the steel members, mainly because he cannot know definitely the precise way in which these other materials will be placed. However, it is very seldom that the steel in a building is left uncovered; it will be encased in concrete, brick, fireproofing, etc., all of which will actually stiffen the structure and act as partial supports to the horizontal members.

Another side of this question of rejection is the moral effect that will sometimes be produced by a judicial action with regard to a few rivets. An inspector should never under any circumstances

be revengeful; he must always be sure that there is some reason for his rejections, but he is justified in being more exacting when he finds that the shop men are inclined to take advantage of his leniency. Again, the shop crew, while not actually doing bad work, may become somewhat lax in their efforts and need a spur to keep them up to the standard. No set rules can be given as to what is the right thing to do in these cases; each problem must be solved when it presents itself by the liberal use of common sense, good judgment, and knowledge of human nature.

Planing and Milling. After each member has been riveted, it is taken to the planers and drill presses where the ends are made square and true, where all bevels are cut and the piece made the proper finished length, and where the pin and other holes are drilled. The inspector should see that all cuts and holes are located in the right places and in accordance with the drawings.

In making measurements, nothing but a good quality of steel tape should ever be used and this should be tested from time to time with a standard measure and correction made if necessary.

When the piece leaves the planer and drill press, it should be thoroughly inspected to see that all the requirements of the specifications and drawings have been fully carried out.

Painting. It is necessary for the inspector to pass on the work before it is painted, because the paint so covers the work that it is difficult to detect many of the errors.

The inspection of the painting should be carefully made. Painting is regarded as a preservative of the steel, but to be effective it must be properly done. The inspector should satisfy himself that the paint used is the brand and quality specified. Adulterations and substitutions, while not often attempted by the good shops, are easy to make, and when made are for the purpose of lowering the cost, not of improving the paint. Whenever there is a suspicion of unfair dealing, chemical analysis of the paint will aid in the detection.

Before the paint is applied, the surface of the steel must be carefully brushed with steel brushes to remove all loose rust and, especially, all loose scale. The surface must also be dry, as water and dampness prevent the paint from adhering, and thus make it possible for rust to start. It is best to have the painting done

in some sheltered place that has a roof, where the temperature is not allowed to get too low.

Daily Record. The inspector should keep a carefully prepared daily record of the work while it is going through the shop, particularly if there is a time limit to the contract. Such a record is usually kept on printed forms with headings so as to simplify the process as much as possible. A good example of a form used is one that has vertical rulings with headings at the top, reading from left to right as follows: Number of Drawing; Name of Piece; Date; Punched; Assembled; Reamed; Riveted; Milled; Painted; Shipped; Remarks.

These records should be made in triplicate, or as many copies supplied as may be required, so that the designing engineer and all those entitled to them may have copies without delay.

Size of Drawings. It is customary to make the shop details on sheets not much larger than specification paper so that the inspector can easily carry the details around with him through the shop. However, if the drawings are large and bulky, the inspector finds his work simplified by entering in a notebook the principal dimensions and other information regarding the different pieces. This notebook should be with him on his inspection tours and should often be referred to.

Loading. From time to time, the inspector should see how the finished steel is being loaded on the cars for shipment. The men will be tempted to throw it in the easiest way possible so as to fill the car quickly. Often the steel is so loaded that the movement and jar of the car seriously injures the metal, causing a delay in the work while it is being repaired. The inspector should insist that the loading be done so that the steel will not be twisted or bent while in transit.

System. As in other things, the more system that the inspector can put into his work, the more and better work he can do. The records suggested above will furnish a means for keeping his superiors informed of the progress of the work, and they will also relieve his mind of numerous details and, consequently, of a certain amount of worry and uneasiness.

One thing that an inspector often overlooks is getting the work out of the shop in a sequence that conforms somewhat to the way

it will be needed at the site. While it is not always economical to push the work through the shop, this matter of sequence is a vital one. The records which the inspector makes greatly aid him to see that no piece is overlooked entirely. Many times the whole building is held up, awaiting the receipt of some small member which has been delayed in the shop or in transit? Having on the site ninety per cent of all the steel of a building going above the first floor does not aid the erector very much if he is short a few of the basement columns. This state of affairs often creates confusion on account of the lack of room to store the material at the site.

Reports. The man who is to superintend the erection of the structure should be supplied promptly with copies of the shop inspector's reports; and if the specifications require mill inspection, with copies of the mill inspector's reports. These should show that all material coming to the site has been accepted by the shop and mill inspectors.

INSPECTION AND SUPERINTENDENCE OF ERECTION

The remainder of this article will deal with the inspection and superintendence of the erection of the structures after the steel and other materials have been delivered at the site of the building.

Kinds of Structure. Some of the different kinds of steel structures that a superintendent encounters in his work are the following:

(1) *Steel skeleton buildings*, where the entire load of the building, both of walls and of interior, is carried on the steelwork or frame.

(2) *Wall-bearing steel buildings*, where the interior loads of the building are carried on steel columns, girders, and beams, but the walls are self-supporting and carry the outer ends of the girders and beams.

(3) *Bridges* of every type and description, divided into two general classes—highway and railway.

(4) *Viaducts*, either for highways or for railroads.

(5) *Subways* under railroads or forming tunnels under city streets for cars or for traffic of any sort.

(6) *Elevated railroads* in cities, of column and girder construction, built for fast-moving trains above the traffic on the streets.

(7) *Miscellaneous* structures, including tunnels, gas tanks, grain elevators, structures in amusement parks, steeples, towers, etc.

Different Methods of Erecting Steel. Various methods used in the erection of steel structures include the diverse ways of applying power, such as steam, electricity, air, or gasoline, through cables, ropes, etc., which are supported on some kind of a derrick, crane, traveler, or similar appliance, the power being increased by the use of pulleys, sheaves, and blocks. The determination of the proper method to be used in erecting a steel structure resolves itself into a separate problem for each individual case. It is here that the skill of the contractor and his erecting engineer is brought into play.

If the steel structure extends upward, usually a derrick or a system of derricks is adopted, of a style and size that can be easily and quickly elevated as the structure progresses. This method applies to tall buildings and towers.

If the structure extends horizontally, like an elevated railroad, a bridge, or a train shed, then some kind of a traveler or system of derricks that can be moved with facility in a horizontal direction is usually adopted.

Before the proper method can be determined, the contractor must ascertain accurately the different conditions that enter into the problem. First the weight and size of the largest and heaviest individual pieces to be erected must be known; then the required speed of erection must be determined, and this will decide the number of derricks or other machines to be used. It can readily be seen that such machines can make only so many moves a day, and that if the pieces are too heavy to be lifted by hand, no matter how many men the contractor may put on the job, the limit of the erection speed of the structure is the limit of the speed capacity of the machine adopted. It is important that a sufficient number of derricks be arranged for, and the superintendent should satisfy himself that the contractor has made no mistake in this respect. Each derrick requires only a certain number of men to operate it properly and economically; therefore the proper number of men employed on a given piece of work is determined by the number of derricks or machines used on that work. The reach or length of boom must also be decided upon. The longer the boom of a given cross-section, the less load the derrick can pick up. It is advisable, too, that all

parts of the structure be reached with as few moves of the derricks as possible, as every move takes time and costs money.

Derrick Layout. If the structure to be erected is a building, a convenient way of arriving at a good derrick layout is to make a plan to scale of the derrick which the contractor would like to use and cut this from cardboard. Place this on the general setting plan of the typical floor, and move it around until the best location is determined upon. In doing this, it must be kept in mind that proper supports for the mast must be provided for, and also proper places of sufficient strength to which the guys or ends of stiff legs can be anchored. If these supports and anchor places can be found in the structure already erected, then a minimum of such work as shoring is required, and an expense in the moving of the derricks saved.

Bridge Traveler. Often when the structure to be erected is an important bridge, the engineer who designs it also designs the traveler or whatever method is to be employed in the erection. By doing this, he makes sure that the contractor will not put undue and unnecessary strain upon the structure during the construction.

Locomotive Crane. It is usual to employ a locomotive crane or derrick car whenever the work is of such nature that it can be reached from a railroad track already in place or which can easily be put in place. A locomotive crane, however, is an expensive piece of machinery and only the large contractors can afford to use one on small jobs. Of course a job may be important enough to make the purchase of a crane desirable.

Capacity of Equipment. It is a very important duty of the superintendent to see that the derricks, travelers, and other machines which the contractor proposes to use in the erection of the work are of a capacity adequate to the work. To determine this, the superintendent must know something of the theory of strains and stresses in materials, and of the theory of design of structures. If he does not have this knowledge, or is in any way doubtful about the strength of the machinery for erection, he should refer the matter promptly to his superior or to some engineer who is capable of advising him correctly. Structures have been known to collapse during erection because of the contractor's carelessness or the contractor's or superintendent's lack of knowledge regarding these matters.

Omission of Small Items. The superintendent should be constantly on the lookout for the omission of the little things, insignificant or trivial to the men, but really important if the structure is to be made safe for holding the equipment.

It is an old and trite saying that a structure is no stronger than its weakest point, but this is a very important fact for every superintendent and every other person connected with the work to remember. Many a collapse has been caused by the omission of small things—a pin, a few bolts or rivets—or by the neglect of a worn-out cable or rope.

To repeat, then, the superintendent must watch the important little things ceaselessly, particularly in a job that is being rushed, where the men are striving to make as big a showing as possible. The superintendent ought to keep in mind that not only the safety of the structure itself but the preservation of the lives of the men, and of his own life, are dependent upon such watchfulness and knowledge.

Another thing that it is well for those in charge of construction work to appreciate is that while it may not take much effort or extra material to keep a thing from starting to move, it takes an enormous amount of effort to stop it after it has once started—so great an effort that it is generally impossible to prevent the collapse of the structure or its parts.

Necessary Risks. It is necessary to take some chances in the building business, but one need not be foolhardy or reckless. As in other things, the superintendent must be so thoroughly familiar with this aspect of the work, that he can tell whether or not the contractor and his men are taking legitimate risks. A superintendent who is too inexperienced or too fearful can often seriously delay the progress of the work by his unnecessary objections and lack of confidence, while another can by his ignorance and carelessness allow the work to be carried on in a positively dangerous manner. However, it is better to err on the safe side, and be too careful, rather than too careless.

Adequate Equipment. Every good contractor knows, too often because of bitter experience, that there is no economy in trying to do work with machinery, tools, or equipment of any sort that is too light or in any way inadequate for the work to be per-

formed. For example, if the men feel that the derrick they are operating is barely strong enough to lift the loads with which it has to deal, they invariably make allowances for this weakness, at a greater expense in wages paid than a good derrick would have cost. If the contractor is trying to get along with a twenty-horse-power engine when the work requires one of twenty-five horsepower, he will lose money; he will make it, however, by installing an engine of thirty or thirty-five horsepower. On the other hand, if the machinery and equipment is larger, more elaborate, or more complicated than is necessary, the erection cost will be unjustifiably large. The capable contractor uses machinery and equipment of size and capacity slightly larger than is required for the work. His rig also is comparatively simple and, as a general rule, he lets others do the experimenting with new rigs and devices.

Good Contracting Engineering. This question of having the rig of proper size and capacity is, of course, nothing more or less than that of good engineering, which means good business. It does not require a very clever man to design an equipment that is either too weak or too strong for the work, but it does require one of skill to have it just strong enough and not too complicated or elaborate. It takes ability to employ men and materials of any sort economically, to know the proper amount of work each should do, and to see that the work is done.

As with machinery, so with workmen; the capable contractor has the right number of men at work. There is no more economy in trying to do a piece of work with too few men than in endeavoring to do it with too many.

Here is another place where it will be seen that the work of the designing engineer differs from that of the contractor and the erecting engineer. The designer concerns himself largely with the economical use of materials, while the contractor is concerned with the economical use of men in handling the materials.

DERRICKS USED IN STEEL ERECTION

Classes of Derricks. The derrick is the steel setter's best friend in the way of machinery, and some form of it is found on every job. It is therefore essential that the superintendent know how derricks are designed and the advantages of the different types.

There are two general classes of derricks, namely, timber and steel; the former type is more common, but the steel type is more durable and is growing in popularity.

Timber derricks are those which have the principal parts built of wooden timbers connected by fittings made of cast iron, malleable

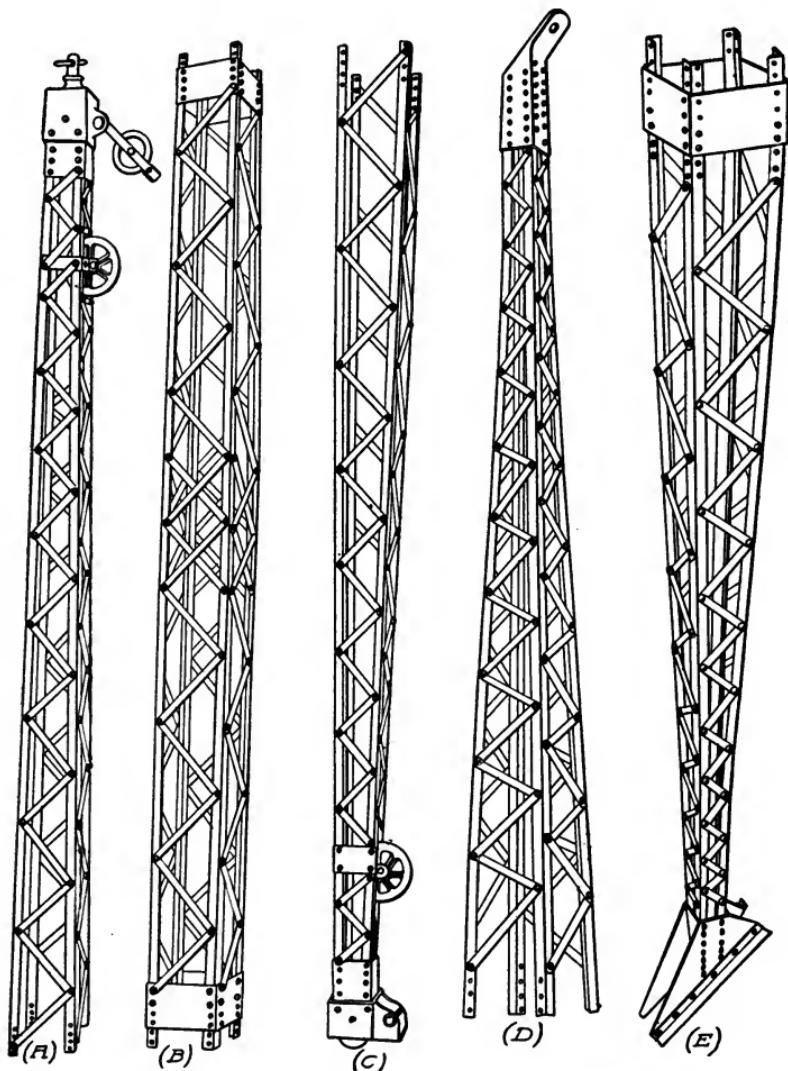


Fig. 1. Types of Structural Steel Used for the Mast and Stiff-Leg in All-Steel Derricks

iron, or forgings. These are the cheapest to build. Some contractors think they are better than steel derricks because they have more elasticity, withstand knocks better, and are lighter to

handle; but they deteriorate more rapidly. Old timbers should always be examined carefully for faults in the wood, especially where it comes in contact with the fittings; such defects as dry rot may affect the strength of the derrick. Good irons and fittings for timber derricks can be purchased from a number of reliable manufacturers in the United States. All such material should be of a size and strength sufficient to withstand the violent strains which are often imposed upon the machine. The irons and fittings should always be somewhat stronger than the timbers on which they are used, and so designed as not to put unnecessary stresses upon the timber. The method of fastening the fittings to the timbers is a most important part of the design of the derrick.

It has been learned that any column carries more if the load is balanced on top of it. A fitting fastened to a timber so that it tends to bend that timber when the derrick is carrying a load is not well designed. The best irons are those which tend to strain the timbers concentrically and not eccentrically. The fittings should also be fastened so as not to split the ends of the timbers.

Steel derricks are those that are built entirely of steel. In Fig. 1, *A* is upper end of mast, *B* the middle interchangeable section, *C* the lower end of mast, *D* the upper end of stiff leg, and *E* the lower end of stiff leg. Steel derricks are now used more than formerly. They can be of stronger construction than the timber ones, and more easily designed so that the strains may be applied concentrically to the different members. Steel derricks do not withstand as hard side shocks as the wood, because the wood springs, while the steel becomes deformed so as to impair its strength. Steel derricks are comparatively expensive to build, but if properly kept up and painted as often as necessary, their life is indefinite; another advantage they have over the wood is that the different members, such as the boom and the mast, can be made in interchangeable sections, which enables the user to lengthen or shorten these members at will with but little trouble.

Capacity of Derricks. The capacity of a derrick depends upon a number of things. The quality of the timbers or of the steel must be considered; only tough, clear, straight-grained sticks, or a good quality of tough mild steel, should ever be used. The size and length of the timbers, or the amount of steel and its dis-

tribution in different members, are also important. The theory of column design enters here; a 16- by 16-inch boom, 60 feet long, does not carry nearly the load that a 16- by 16-inch boom, 30 feet long, carries. Again, the spread of the metal in the cross-section of a steel member affects its capacity. For instance, if we have two booms, each 80 feet long and built up of four angles of the same size and shape laced together, one having the angles spaced back to back 15 inches and the other 30 inches, the latter will be found to carry much more than the former.

Other things influencing the capacity of the derrick are the ratio of the length of the boom to the mast, the ratio of the spread of the guys to the length of the mast, the length of the sills to the length of the mast in a stiff-leg derrick, and so on. The shorter the mast is for a given length of boom, the smaller the capacity; the nearer the guys of a guy derrick are anchored to the foot of the mast, the smaller the capacity; and the shorter the sills are for a given length of mast in a stiff-leg derrick, the smaller the capacity.

The capacity also depends upon the strength of the irons and fittings, and in the manner in which the loads are applied to the timbers through these; the way in which the fittings are fastened to the timbers; and the number of bolts and rivets used.

The capacity of a boom, mast, etc., can be increased by means of a 4-rod truss, Fig. 2.

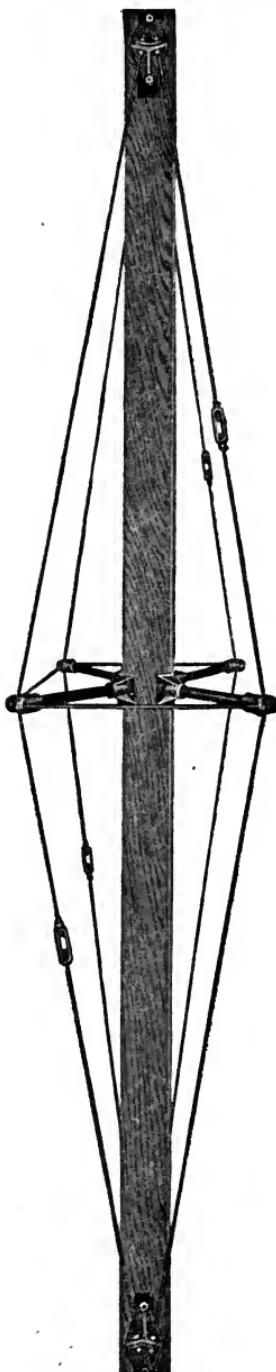


Fig. 2. Boom with 4-Rod Truss
Courtesy of Clyde Iron Works

Approximate Strains upon Guy and Stiff-Leg Derricks. A simple way of arriving at the approximate strains imposed upon a guy and upon a stiff-leg derrick is given below. It must be kept in mind, however, in applying the results thus obtained,

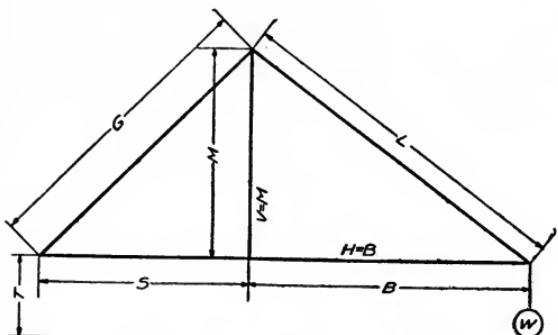


Fig. 3. Strain Diagram for Guy and Stiff-Leg Derrick—Boom Horizontal

that the capacity of the derrick will be modified by some of the items mentioned above. (See Figs. 3, 4, 5, and 6, which are diagrams of a derrick showing various positions of the boom.)

Let M = length of mast; B = length of boom; L = length of topping lift;

G = length of guy or stiff leg; S = length of sill; V = vertical distance from top of mast to a line drawn at right angles to mast through end of boom; H = horizontal distance along this line from mast to end of boom; W = load in pounds; and T = strain in pounds on tie-down or anchor.

Then (1) the compression strain in pounds on the mast =

$$\frac{LWM}{MS}, \text{ to which } \frac{VW}{M}$$

must be added if V is below the top of the mast, or subtracted if V is above the top of the mast. If V above the mast becomes long enough, the strain on the mast will become tension instead of compression.

(2) The compression

strain in pounds on boom = $\frac{BW}{M}$; tension strain in pounds on topping lift = $\frac{LW}{M}$; tension strain in pounds on guy or stiff leg = $\frac{LWG}{MS}$;

Fig. 4. Strain Diagram for Guy and Stiff-Leg Derrick—Boom Angle with Horizontal Less than 45 Degrees

compression strain in pounds on sill = $\frac{BWH}{MB}$; and vertical tension strain in pounds on the tie-down or anchor =

$$\frac{(\text{strain in pounds on guy or stiff leg}) \times M}{G}$$

Note that if this strain is directed in any direction other than at right angles to sill, the amount of strain will vary with the angle of direction. The student should apply the above formulas to a number of derricks of different proportions and with the boom in various positions—from the horizontal almost to the vertical—and note how the strains in the different members change as the proportions and the positions of the boom change. If the student does his work rightly, he will observe the following facts:

(1) When the boom is in a horizontal position, directly opposite to a stiff leg or guy and in line with it, all the members of the derrick in line with the boom are subjected to the greatest strains that can be put upon them by the ordinary method of loading, with the exception of the compression strain on the boom, which does not change for any of the varying positions the boom may be in. However, a horizontal boom is not so strong as a vertical one because its own weight tends to sag it at the middle. Therefore it will be seen that the limit of the capacity of a guy or stiff-leg derrick is the load that can safely be lifted by it when the boom is horizontal.

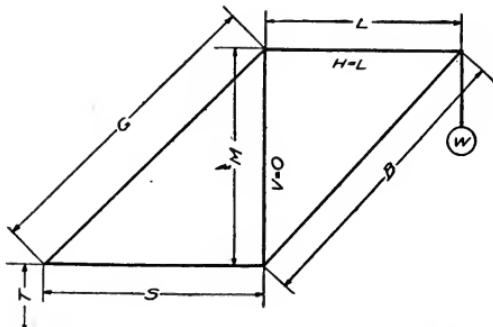


Fig. 5. Strain Diagram for Guy and Stiff-Leg Derrick—Boom Angle 45 Degrees

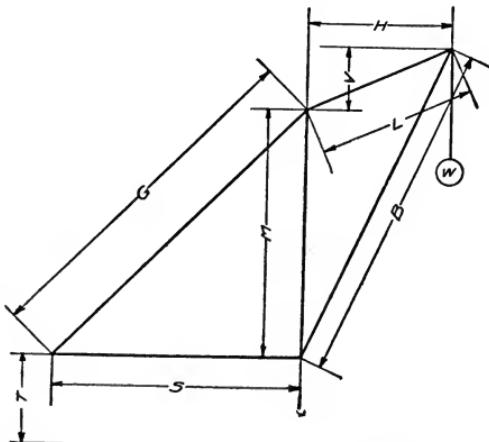


Fig. 6. Strain Diagram for Guy and Stiff-Leg Derrick—Boom Angle with Horizontal Greater than 45 Degrees

(2) As the boom is made shorter or the mast longer, the strains on all the members of the derrick decrease; while as the boom is made longer or the mast shorter, these strains increase.

(3) The length of the sill does not affect the strain on the sill itself; as it is made longer, however, less strain is put upon the stiff leg, its tie-down or anchor, and upon the mast, but this strain

does not affect those on the other members. As the sill is made shorter, a greater strain is put upon the stiff leg, its tie-down or anchor, and upon the mast, but this does not affect those on the other members.

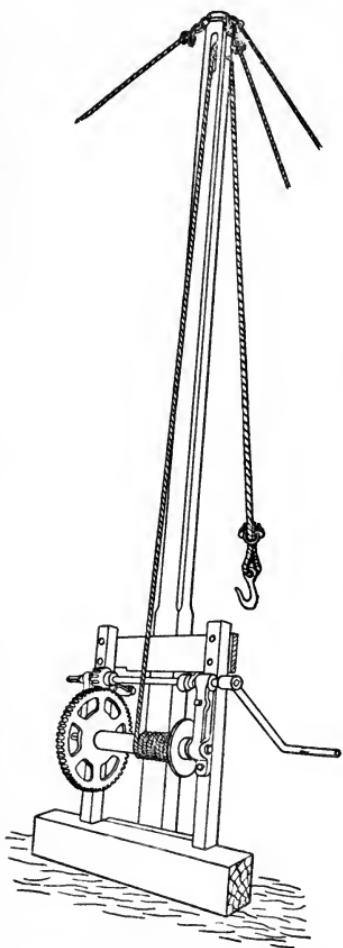
(4) The greater the angle made by a guy and the mast, the less is the strain on the mast and on the guy, if the weight of the guy itself is ignored. This angle of the guy to the mast does not affect the strains in the boom and topping lift but does affect the pull on the anchors.

Types of Derricks. The principal types of derricks used in the erection of steel structures are pole derricks, or gin poles; builders' or house derricks, sometimes called setters' and breast derricks; guy; stiff-leg; full-circle stiff-leg; combined stiff-leg and guy; A frame; crane derricks; and tower derricks.

Pole Derrick. A pole derrick, Fig. 7, more often called a gin pole by the bridgemen, is merely a pole or single stick, guyed at the top to keep it from tipping over, with some kind of a block

or a sheave fastened at the top, and a crab or a snatch block fastened at the bottom, the purpose of the snatch block being to lead the hoisting rope to the hoisting engine, or whatever power is used. This kind of a derrick is light and can be erected by hand, but its range of action in one place is limited to practically one lift, and if moved, that must be done by hand. It has been found that the cost of

Fig. 7. Typical Pole Derrick



moving as compared to the number of lifts that can be made in a day, makes this derrick an expensive tool for setting steel generally. It is, however, almost always used in one form or another in the setting-up of the larger derricks, as it can be put in place by the men without the use of other power.

Builders' or House Derrick. A builders' or house derrick, Fig. 8, sometimes called a setters' derrick and also breast derrick is an improvement upon the gin pole. It needs to be guyed in two directions only, front and back, the derrick being stiff enough to brace itself sideways; the gin pole should have at least four guys. The house derrick is somewhat easier to move than the gin pole, as it can be rolled sideways on the two small wheels fastened to the sill. Like the gin pole, it is generally light and can be set up by hand, but it has the same limitations as the other in that it must be moved practically each time a new lift is made. The capacity of this kind of derrick is comparatively small; it is found mostly on the smaller jobs, though it is useful in a limited way on almost every job. It is also employed in setting up the larger derricks. Stone setters, however, make more use of it than steel men.

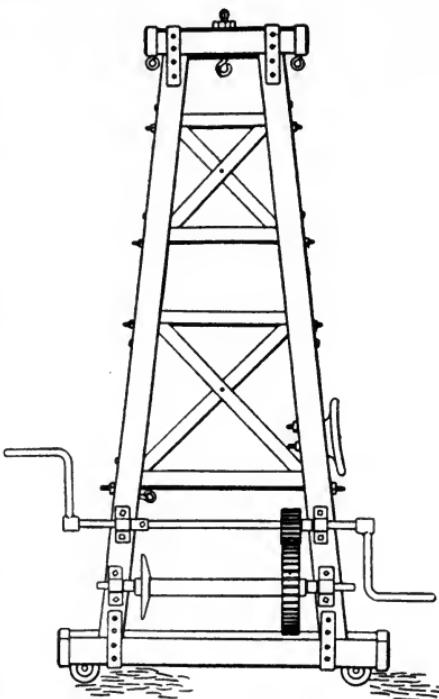


Fig. 8. Builders' or House Derrick

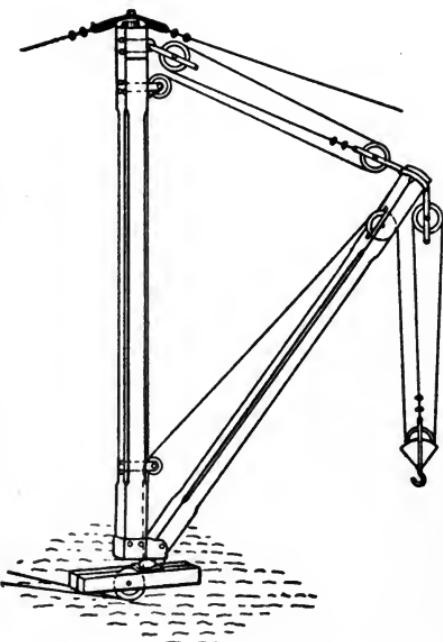


Fig. 9. Diagram of Guy Derrick

Guy Derrick. The guy derrick, Fig. 9, is composed of a mast and a boom. The mast is held upright by means of guys, from four to eight in number, made of ropes or steel cables; it is pivoted top and bottom, which allows it to revolve. The boom is fastened to the mast by means of a pin, which enables it to take any position between the horizontal and the vertical. It revolves with the mast. It will therefore be seen that a lift can be made at any point within a circle which has for its radius the length of the boom, without changing the location of the derrick. The boom should never be allowed to drop beyond the horizontal, as this

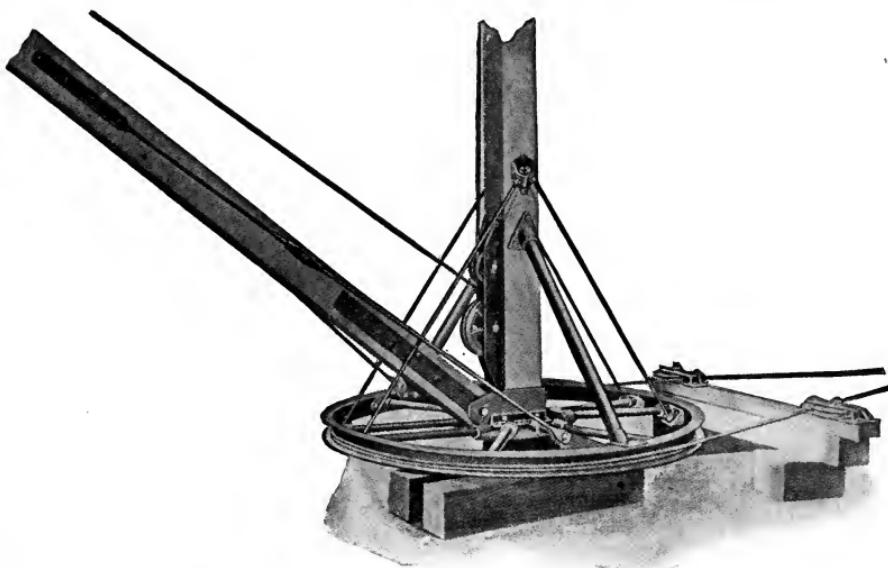


Fig. 10. Bull Wheel Used on Derricks for Swinging Boom
Courtesy of Clyde Iron Works, Duluth, Minnesota

tends to lift the mast out of its seat, and so to cripple the derrick. Many a serious accident has resulted from this cause. The guy derrick is a common style used by steel men. It will cover a complete circle, and it is easy to raise from one story to another, without the use of a gin pole or a house derrick. To do this, the boom is unshipped from the mast after it has been brought to a vertical position; it is then lifted by means of the mast to the new level, guyed like a gin pole, and used to lift up the mast. A guy derrick must always have a mast at least ten feet longer than the boom, in order that the boom shall go under the guys. The great drawback to the use of this style of derrick on a building is usually the

difficulty of finding spread enough for anchoring the guys, because, unless the guys have a great slant or spread, it is necessary to top up the boom each time it is desired to pass a guy. It is almost always found that the extra time consumed in topping up and lowering the boom, in order to get under the guys, more than offsets its advantage of easy elevation.

Bull Wheels. Bull wheels, Fig. 10, are used on guy derricks and on other styles also, in order that the derrick may be slewed by the same engine that operates the hoisting ropes. A bull wheel

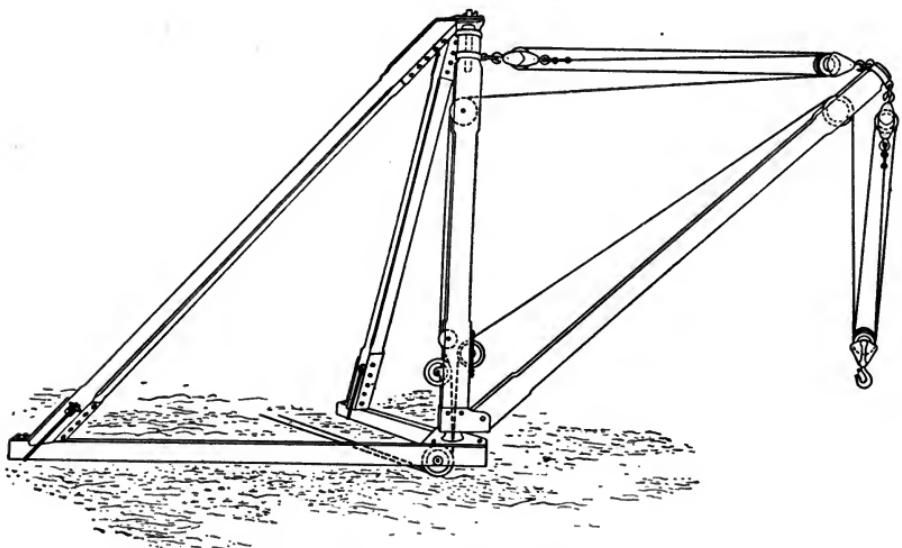


Fig. 11. Diagrammatic Layout of Stiff-Leg Derrick

is seldom used on a building job, however, because it interferes somewhat with the raising of the derrick from one floor to another.

Stiff-Leg Derrick. The stiff-leg derrick, Fig. 11, is probably the most common one used today as it has several advantages over the guy derrick, although it has its disadvantages as well. This type is like the guy derrick, except that in place of the guys it has two slanting members called stiff legs, placed at right angles to one another to keep the mast in an upright position. The stiff legs are subjected to both tensile and compressive strain, depending on the position of the boom.

One advantage of this derrick is that only two anchoring places are needed. Another is that the boom can be much longer than

the mast, sometimes as much as three times as long though usually from one and one-half to two times as long. It can cover only three-fourths of a circle while the boom is loaded. The boom without load can be slung in behind the stiff legs by lifting one stiff leg while the boom passes by, the other being guyed temporarily. This is often done where only one derrick is used, but two or more derricks are generally needed, in which case they are placed so as to help each other, especially in moving up from one story to another. It is generally found, also, that on account

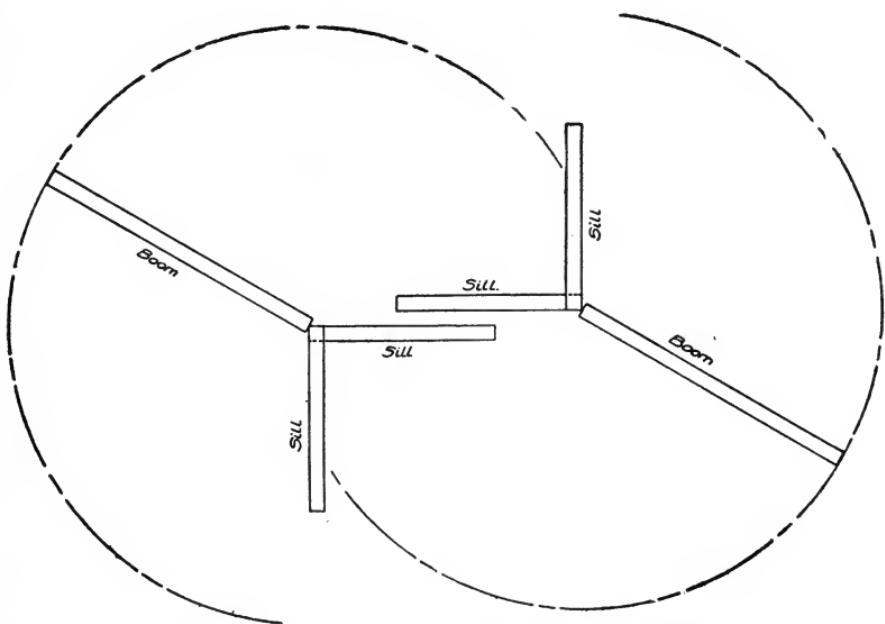


Fig. 12. Plan of Layout for Two Stiff-Leg Derricks

of the longer boom which may be used, as much area can be covered as by a guy derrick, if not more, and there are no guys to interfere with the movement of the boom.

Where the job is large enough for two stiff-leg derricks, a good arrangement is that shown in Fig. 12. It will be noticed that a complete circle is covered by the two derricks and because of the longer booms this circle is larger than if one guy derrick were used; consequently the work can go on much more than twice as rapidly. The derricks are in such position that they can lift one another up from level to level.

Preventer Guys. Because the boom is longer than the mast, it can readily be seen that as the boom takes a nearly vertical posi-

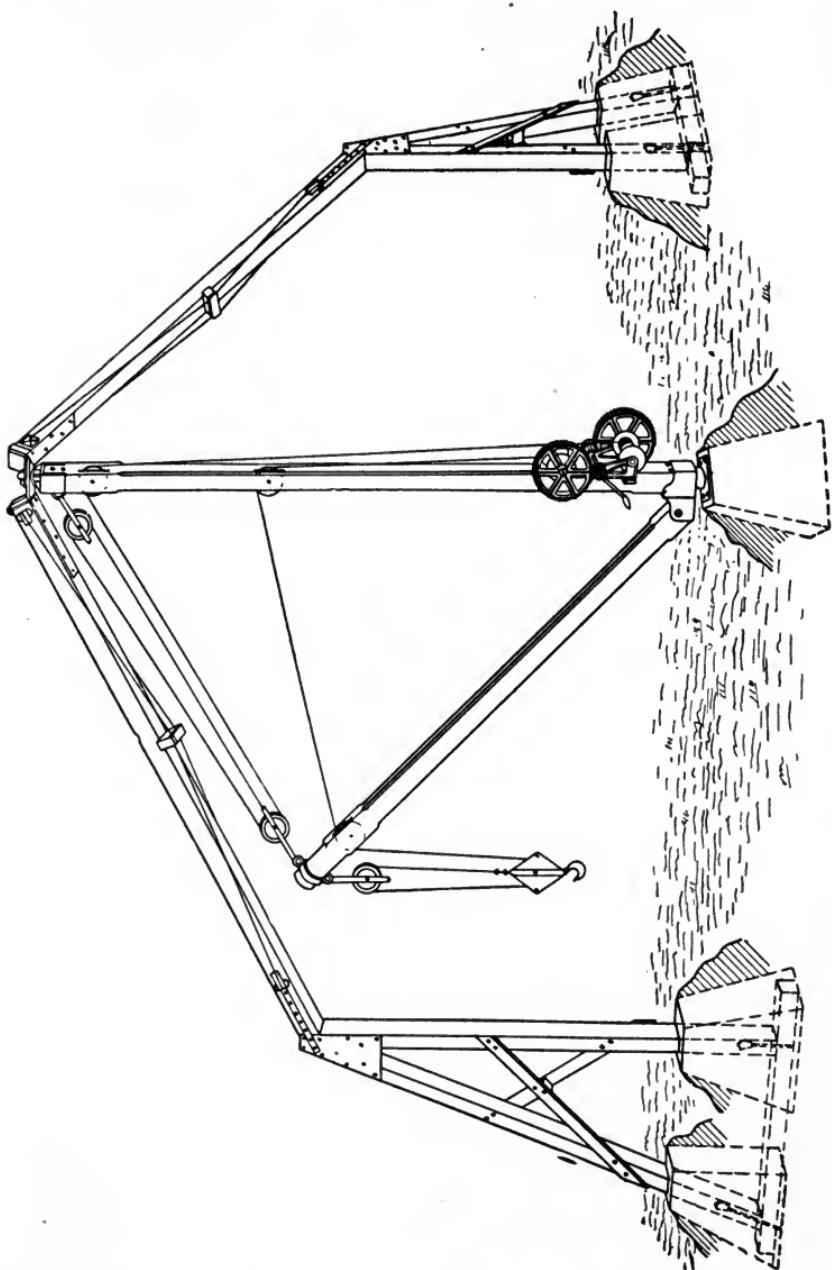


Fig. 13. Diagram of Full-Circle Stiff-Leg Derrick

tion, a strain is exerted tending to lift the mast. Generally, the fittings of the derrick are not designed to resist this strain and

unless preventer guys, as they are called, are used, the mast is unshipped from its seat and the derrick collapses. These preventer guys are ropes fastened to the top of the top stiff leg and to the sill below the seat of the mast. They take up the vertical strain and prevent the mast from leaving the seat. The superintendent

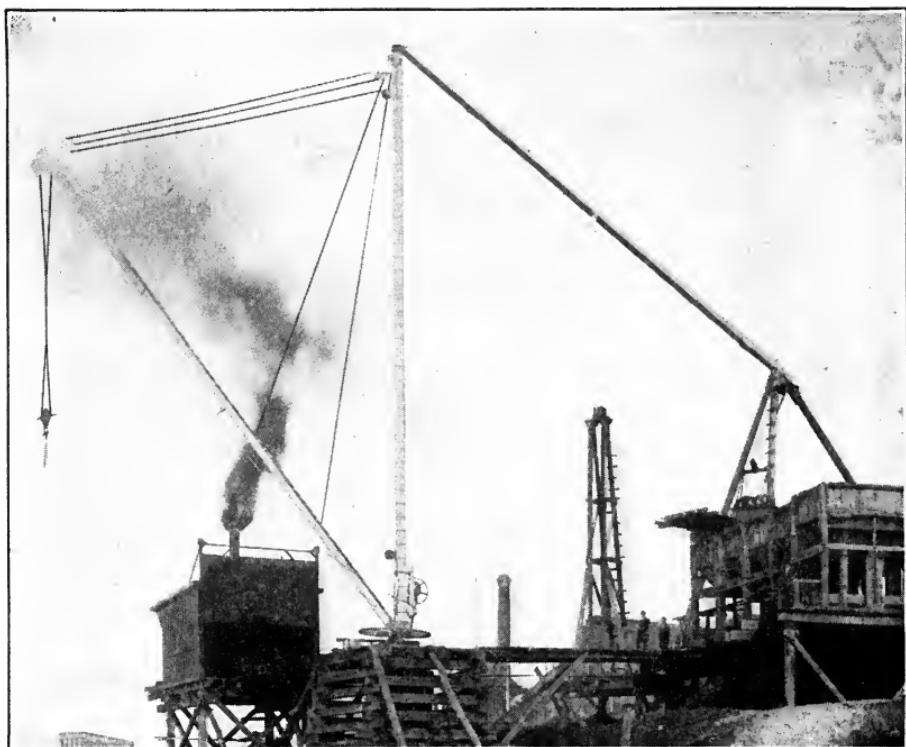


Fig. 14. Combined Stiff-Leg and Guy Derrick
Courtesy of American Hoist and Derrick Company, St. Paul, Minnesota

should always insist that they be used, as the lack of them often causes serious accidents.

Full-Circle Stiff-Leg Derrick. This type of derrick, Fig. 13, and the combined stiff-leg and guy derricks, Fig. 14, are modifications of the stiff-leg and the guy derricks. They are but seldom used in steel erection and only where special conditions make them advantageous. These derricks are not so easily erected as other derricks and therefore are usually adopted on jobs where a minimum of moving from one location to another is required such as in a storage and sorting yard.

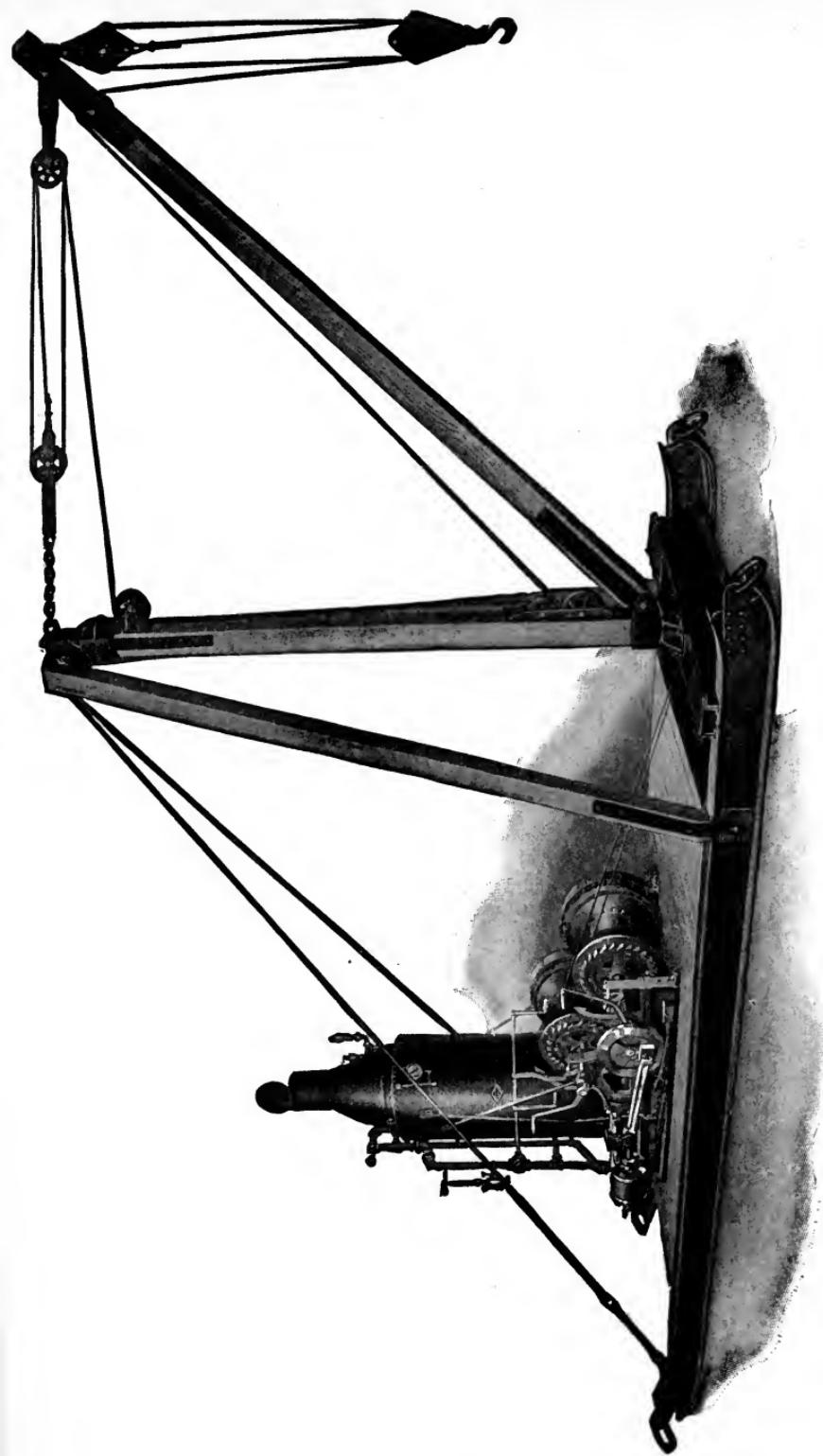


Fig. 15. A-Frame Portable Derrick
Courtesy of Clyde Iron Works, Duluth, Minnesota

A-Frame Derrick. An A-frame derrick, Fig. 15, is generally adopted where a derrick is needed that can be pushed around and easily moved horizontally. It is almost always mounted with the hoisting engine on a flat car or some movable platform. This form of rig is well adapted to jobs in which the steel work is not very high but covers considerable ground.

Where sufficient width of room is available and where a traveler of some kind is needed, two stiff-leg derricks, Fig. 16, fastened together and mounted on a movable platform make a good rig.

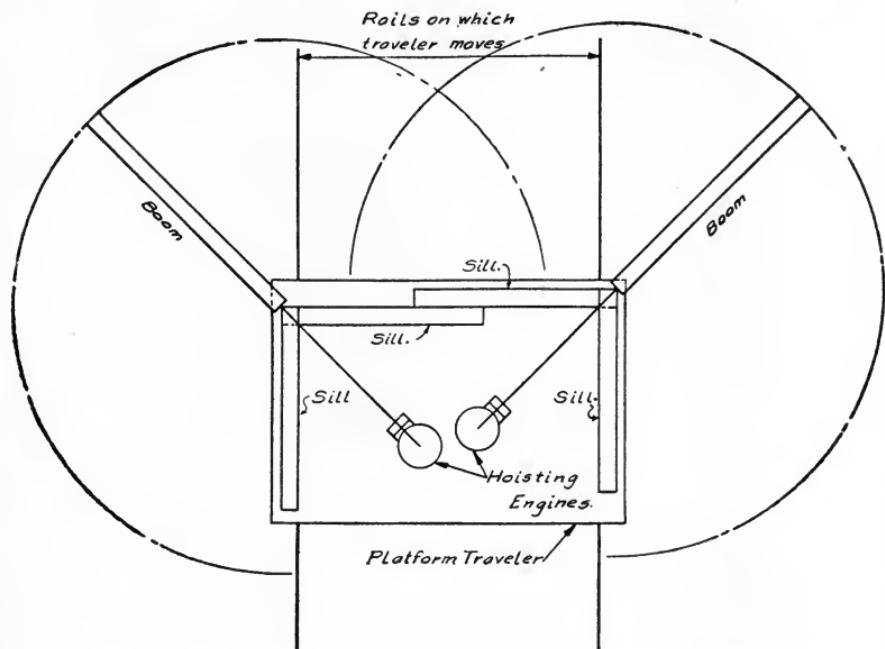


Fig. 16. Plan of Layout for Two Stiff-Leg Derricks on Movable Platform

Crane Derrick. A crane derrick, Fig. 17, is composed of a mast held in an upright position by guys or full-circle stiff legs. The boom is fixed permanently to the mast in a horizontal position near the top. On the boom is a trolley which shifts the load in the horizontal direction. This style of derrick is comparatively limited in capacity, but is useful where a large number of light loads have to be handled. It requires less power to move the loads horizontally, as is readily seen, for the trolley can be moved more quickly and with less effort than is required to top up a long boom attached to a guy or a stiff-leg derrick, especially when this

boom is loaded. It is essential that a crane derrick shall have guys of large spread and fastened in some manner so that the boom can clear them as it swings past. In building work where the steel goes up to some height, sometimes a trestle work or a tower is

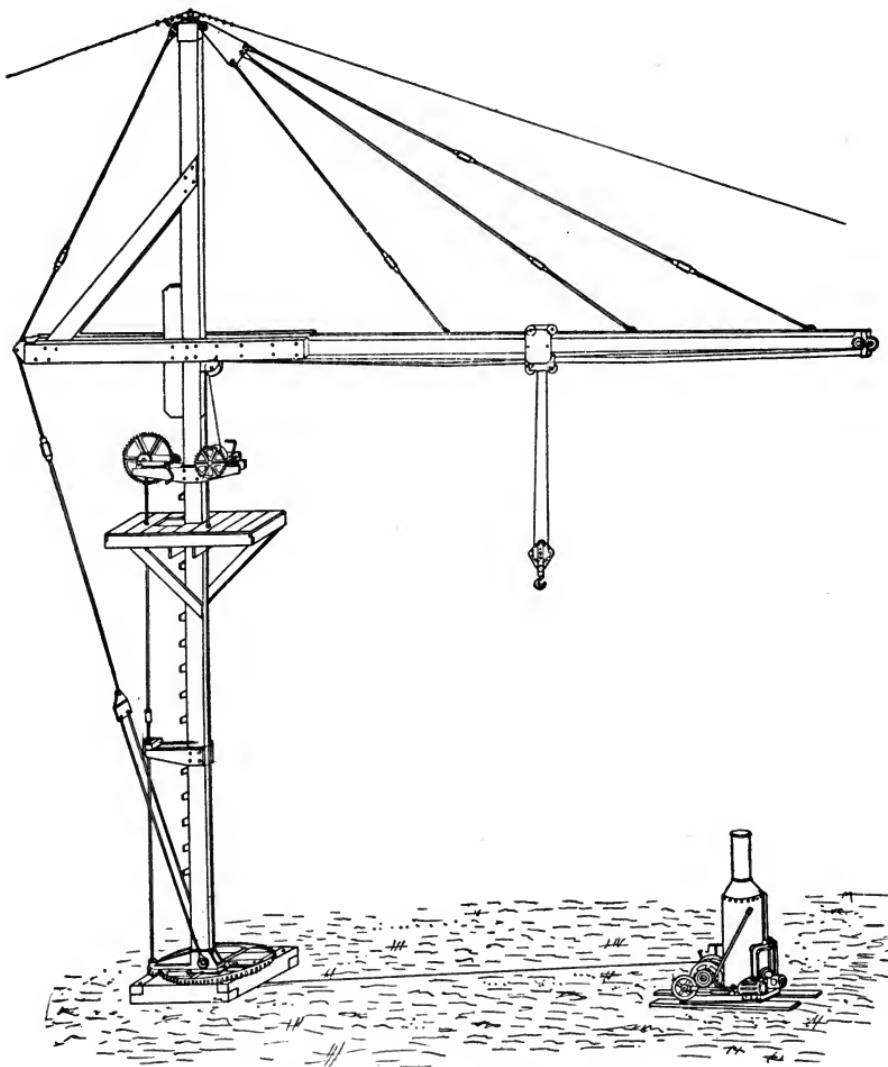


Fig. 17. Diagram of Crane Derrick

erected first and a crane derrick located on top of it. In this way the machine needs to be set up but once to complete the part of the building within its reach. It is estimated that the cost of the trestle or tower upon which the derrick is placed is more than offset

by the saving in the cost of the several lifts of the derrick which would be required if it went up with the steel structure.

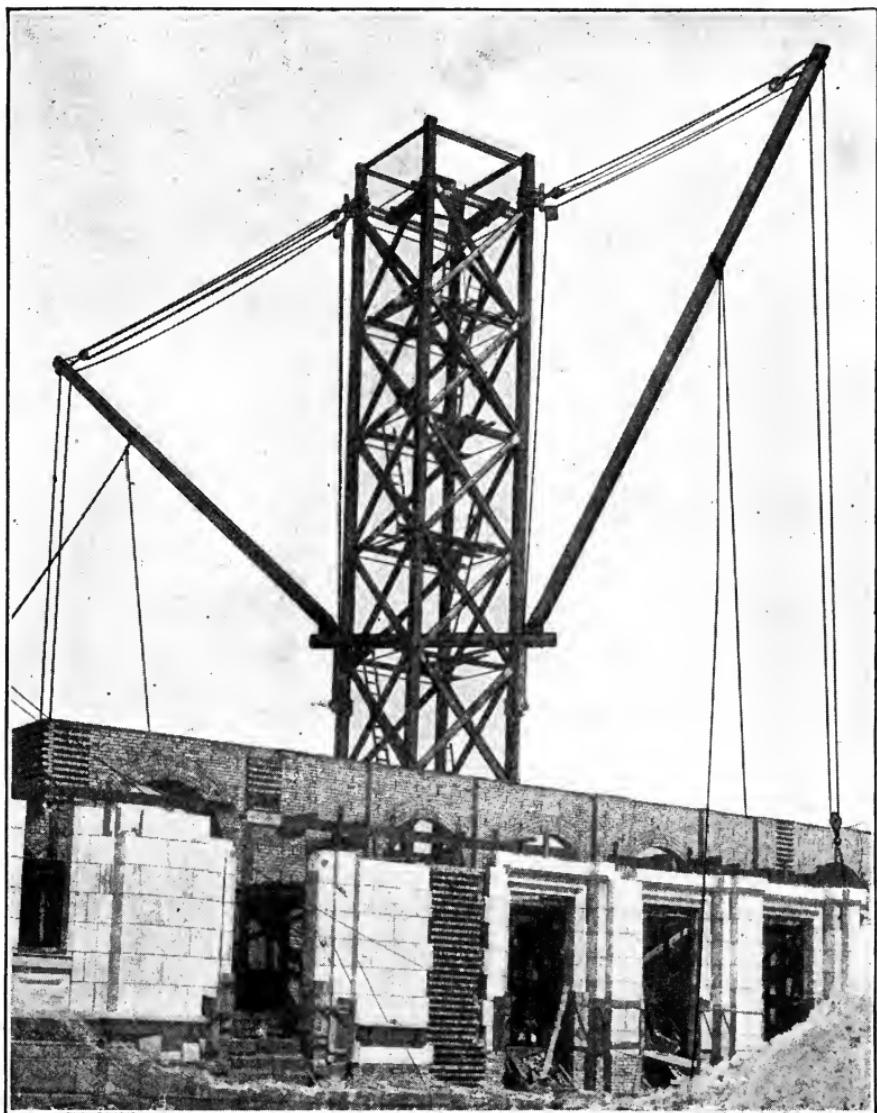


Fig. 18. Tower Derrick Handling Building Work
Courtesy of American Hoist and Derrick Company, St. Paul, Minnesota

Tower Derrick. Tower derricks, Fig. 18, as the name implies, are fastened to a tower and need no guys, stiff leg, or other support to keep the mast in an upright position. Where these derricks are used, a tower must be built ahead of the structure. The derrick

is either moved up on the tower as the structure rises, or it is first placed as high as is necessary to complete the part of the structure within its reach. This form is seldom used except on jobs where

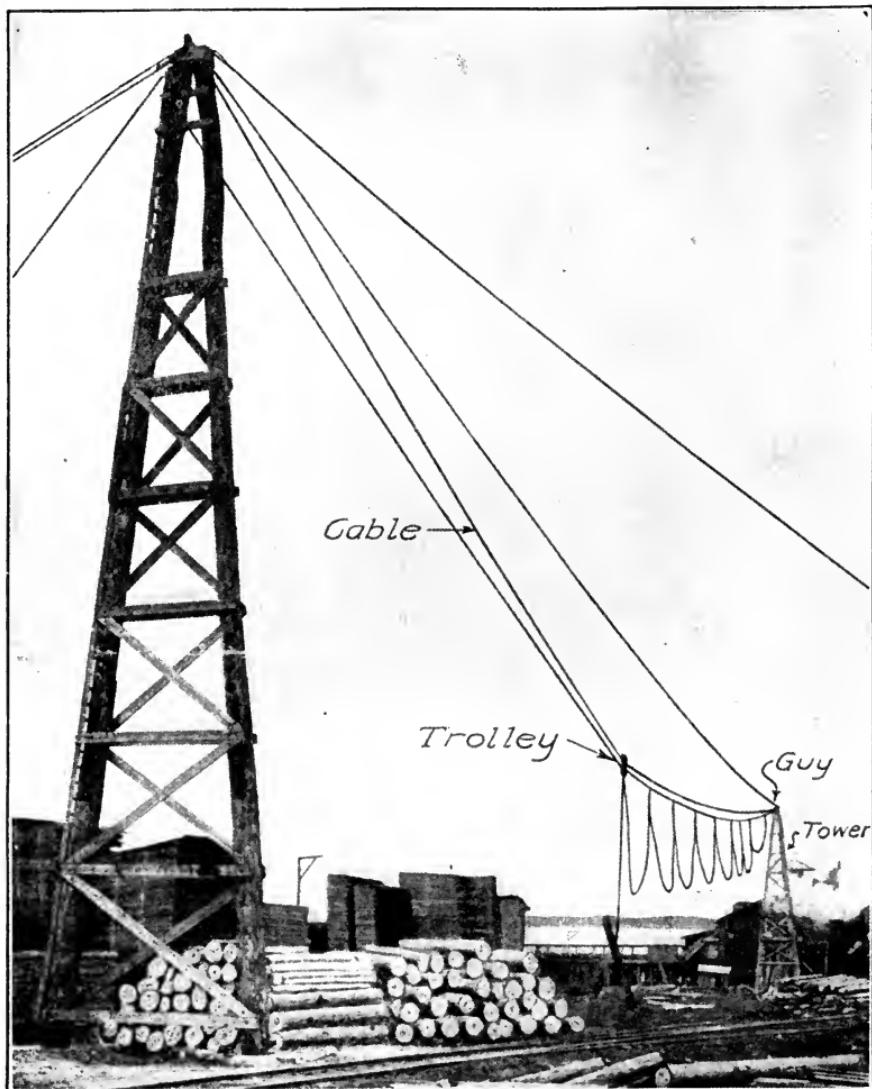


Fig. 19. Typical Cableway Used for Log Storage. This same carrying device can be applied to building situations where location of any type of derrick is not feasible

Courtesy of Clyde Iron Works, Duluth, Minnesota

there is no place available or convenient in the structure on which to locate a guy or a stiff-leg derrick. Some contractors, however, believe that a tower is the cheaper method, because they estimate

that the cost of its construction is less than the cost of raising a stiff-leg or a guy derrick several times, especially when the tower is designed so that it can easily be taken apart and used on other work, and the first cost can thus be divided among several jobs. Tower derricks are commonly used in connection with the travelers employed in the erection of bridges.

Cableways. In some kinds of work it will be found that there is no feasible way of setting up a derrick of any kind, and in such a case some sort of a suspension cableway can be used to great advantage. A cableway, Fig. 19, is composed of a strong steel cable suspended over the work and between towers which may be of the fixed, semi-portable, or traveling type. The load is moved along the cable by means of some kind of a trolley. The rapidity of erection with a cableway is usually much less than where a derrick is used, because the latter can make so many more moves in a day than can the former.

Superintendent's Authority over Equipment and Work

Interference with Contractor Ill-Advised. The superintendent ordinarily has little authority over a contractor's equipment. It will usually be found that the contractor is capable of selecting a good method for doing his work. A superintendent has no right to dictate what equipment a contractor shall use, or to interfere in any way in the matter, unless he is convinced that the chosen equipment is positively dangerous, or can prove that it is insufficient to perform the work within the time limit mentioned in the contract. It is usually a somewhat delicate matter to interfere with the methods adopted by a contractor, and for this reason it is most essential that the superintendent shall have a thorough knowledge of contractors' equipment in general. This knowledge will enable him to stand firm and to prove his contention in any case where he finds it necessary to interfere. It is not sufficient reason for interfering that the superintendent simply thinks he has a better way than the contractor; the contractor may, however, welcome a good suggestion, as a suggestion. Only when the superintendent is convinced that the equipment is positively inadequate to perform the work properly within the given time, is he justified in protesting. It must be kept in mind that the law will hold in a great majority

of cases that the engineer cannot hold a contractor responsible for the results, nor penalize him if results are not obtained within the required time, if the superintendent at the same time has dictated to him what methods he should employ. If the engineer dictates the methods, he must also relieve the contractor of responsibility for the results. It is not generally wise to dictate; it is much better, particularly where the contractor is reasonably capable, to make him responsible for certain results and, at the same time to leave him free in his choice of the methods. In this connection, it is well to remember that the contractor's practical training makes him generally a better judge than the superintendent in his particular field. It is also reasonable to consider that it is vitally to the contractor's own interest to select the best and safest way. On the other hand, the superintendent may be called upon to deal with a dishonest contractor, or one who is ignorant regarding certain parts of his business; in that case the superintendent should not hesitate to interfere and to make his interference felt.

Honest and Dishonest Contractors. We are assuming, however, that the superintendent is called upon to work with contractors who are competent, reasonable, and honest. In most cases where the engineer or superintendent shows these characteristics, the contractor will be found trying to do what is right according to his judgment. It is good policy to assume that a contractor or any other man is honest until proved otherwise. It cannot, however, be denied that there are men in the contracting business who are trying to make money by dishonest methods. Whenever the superintendent comes in contact with such a man, he must take especial care always to be technically correct, because there is no man who is more likely to take advantage of a superintendent's technical mistakes and profit by them, than is the dishonest contractor, especially where it has been necessary for the superintendent to find considerable fault with the work.

Overloading Structures. In addition to the superintendent's duty of ascertaining whether or not the contractor's equipment is adequate, there is the duty of seeing that the structure is not overloaded. In the rush of work, steel men are prone to overload some portion of the structure, either by providing insufficient support for their equipment or by piling too much material in some par-

ticular part. They often do this innocently, not realizing the danger, and the superintendent generally finds that only a word is necessary to rectify the state of affairs. He must always insist, however, that it be corrected without delay.

A guy derrick should have good support under the shoe of the mast and ample strength in the places where anchors are to be fastened. The stiff-leg derrick should have three places of support, namely, under the mast and under each of the ends of the two stiff legs, these last two supports being sufficient to withstand not only the compression strain but also the tension strain which may be placed upon the stiff legs, depending upon the position of the boom.

Hoisting Engines. *Location.* The hoisting engine should always be located in some place where the vibration of it when in action is not transmitted to the structure. The continued vibration of a reciprocating steam engine, air compressor, or similar machine puts undue strains on the structure, tending to make the operation unsafe. To save the structure from this vibration the hoisting engine is left in the basement while the derricks are raised with the structure.

Bracing. It is well to remember that the hoisting engine must be properly braced and anchored, otherwise it is likely to go skidding over the lot when an attempt is made to pick up a load. The steel men are not often negligent in this matter of supports and anchors for the engines, but nevertheless the superintendent should not overlook the inspection of them. Supports and anchors should always be placed in the direction opposite to that of the pull of the hoisting rope. If the engine is located directly under a derrick, then there must be enough weight to hold the engine down; otherwise, instead of lifting the load, the engine will lift itself. The superintendent more often finds that the steel men forget some small things, such as a few rivets in the connections of the beams and girders, which to them seem insignificant. Nevertheless, there is little use in providing a strong and expensive derrick if the support for it is neglected, even in the little items.

Tackle

Classification. Tackle comprises the cordage, ropes, cables, chains, and all fastenings, connections, and other fittings, also all blocks, pulleys, and sheaves, which are required in the work.

TABLE I
Specifications for Standard Chains

SIZE OF CHAIN (in.)	CENTER OF ONE LINK TO CENTER OF NEXT LINK (in.)	OUTSIDE LENGTH OF LINK (in.)	AVERAGE WEIGHT OF CHAIN PER FOOT (lb.)	AVERAGE SAFE WORK- ING LOAD (tons)
$\frac{1}{2}$	$1\frac{11}{12}$	$2\frac{3}{8}$	$2\frac{1}{2}$	From 2 to 3
1	$2\frac{1}{2}$	$4\frac{5}{8}$	10	From 8 to 10
$1\frac{1}{2}$	$3\frac{7}{8}$	7	23	From 19 to 22
2	$5\frac{3}{4}$	10	40	From 32 to 36
$2\frac{1}{2}$	7	$12\frac{1}{4}$	65	From 50 to 56
3	$7\frac{3}{4}$	14	86	From 64 to 72

There is nothing in all the contractor's equipment that is so often deceptive concerning its quality and condition as the tackle. New-looking rope may not necessarily mean that it is stronger than other rope of the same size which does not look so new, for the strength of the rope depends upon what it is made of, how old it is, and how it has been kept.

Chains. Chains, the least dependable part of tackle, are considered treacherous by some men. No chain, unless it has been made by a capable and reliable manufacturer, and has been properly tested, should ever be permitted upon an erection job. It will be seen that because of the way a chain is made—each link welded separately, usually by hand—that it is difficult to get uniformity in the strength of the different links. The strength of the chain depends upon the quality of the iron, its composition, the degree to which the iron has been heated (iron that has been burned is weakened), what the temperature was during the process of welding, and how carefully the welding is done—all of which may vary in degree, thus affecting the strength of the finished chain.

No chain should be expected to do more than it was designed for. Every time a chain is overloaded beyond a certain limit, it is weakened.

All chains in actual use are subject to deterioration, apparent and invisible; the apparent being the wear of the links where they come in contact with each other or with other things, the invisible being an alteration in the nature of the material or of its fiber, caused by shocks, strain, and frost, which produces crystallization. This crystallization can be remedied by frequent annealing, which

TABLE II
Weight and Strength of Manila and Sisal Ropes

DIAMETER OF ROPE (in.)	LENGTH OF ROPE WEIGHING ONE POUND (ft. or in.)	AVERAGE STRENGTH OF NEW MANILA ROPE (lb.)	AVERAGE STRENGTH OF NEW SISAL ROPE (lb.)
$\frac{1}{2}$	13 $\frac{1}{2}$ ft.	2000	1400
$\frac{3}{4}$	6 ft.	4000	2800
$\frac{7}{8}$	4 ft.	6000	4200
1	3 $\frac{1}{2}$ ft.	7000	5000
$1\frac{1}{4}$	26 in.	11000	8000
$1\frac{1}{2}$	18 in.	16000	11500
$1\frac{3}{4}$	12 in.	22000	16000
2	10 in.	28000	20000

is done by heating the chain to a cherry red and allowing it to cool slowly. A chain should be annealed at least twice a year.

The size of a chain is that of the diameter of the iron out of which the chain is made. Table I gives some of the characteristics of chains.

Cordage. Cordage is made principally out of the various grades of hemp, jute, sisal, and cotton, all of which are fibers from different fibrous plants.

Manila Hemp. The strongest rope is the Manila rope, made from the best quality of Manila hemp, a product of the Philippine Islands. There are on the market from twenty to thirty different grades of Manila hemp varying from a specially fine grade of long, clean, white, strong fibers, to an inferior grade with short, dark fibers. Cheap rope has short fiber and heavy weight; often weight-making adulterants are added.

Real Hemp. Real hemp is a native of central and western Asia, but is extensively cultivated in many countries. There are various plants which have fibers of similar nature and which are called hemp but which in reality are plants of other genera. Manila hemp is not a real hemp, as it comes from one species of the musa plant, another species of which is the banana plant.

Jute. Jute comes from a plant called Jews' mallow, is a native of Bengal where most of the jute used in commerce is produced. It is of inferior value for ropes for it does not stand moisture well.

Sisal. Sisal comes from sisal grass, sometimes called sisal hemp, which is obtained principally from the agave plant, a native

of Yucatan. Rope made from this fiber weighs about the same as Manila, but is only about five-sevenths as strong. It resists dampness, however, better than hemp and is stiffer than Manila, and for that reason is sometimes preferred. Table II gives various facts relative to the weight and strength of Manila and sisal ropes.

Cotton Rope. Cotton rope is seldom used by steel setters except in the small sizes, for signal ropes, etc.

Wire Rope. There are many different kinds of wire rope, varying in quality of material, lays and number of strands, and twists and number of wires in the strands. Only that kind of wire rope adapted to the work it has to perform should be used. It is false economy to use cheap rope for such purposes as hoisting, because the cheaper rope has to be replaced so often that the total cost equals the cost of the best grade. A wire rope may be made of 114 wires, but if one of these wires becomes broken, the rope is unsafe for further use in connection with pulleys, sheaves, and blocks, as the broken strand may unravel and rap itself around the sheave. If the wire happens to entangle itself in the sheave or block, and the power is not shut off promptly, there is great danger that the block or sheave will be torn from its support and drop the load.

Wire rope is usually made with a hemp center. This center, essential to the pliability of the rope, acts as a cushion around which are laid the strands. Where the rope is to be used without bending, or is not to be moved from one location to another, rope with a wire center is sometimes used.

Wire rope is usually made of 6 strands, which in turn are composed of 7, 9, 12, 19, or 37 wires, each, a finished rope having, thus, 42, 54, 73, 114, or 222 wires.

Ropes made of 6 strands, each strand of 19 wires, are best adapted for hoisting purposes. Those made of 6 strands, each strand of 7 or 12 wires, are best adapted for guys, rigging, and straight haulage purposes.

As usually constructed, the wires in the strand are laid or twisted in one direction, while the strands composing the rope are laid in the opposite direction. Where the rope will probably be subjected to great crushing force or pressure, one constructed with the wires in the strands laid in the same direction as the strands themselves will wear longer.

TABLE III
Specifications for 6 x 19 Hemp-Center Wire Hoisting Rope

DIAMETER OF ROPE (in.)	WEIGHT PER FOOT (lb.)	MINIMUM DIAMETER OF DRUM OR SHEAVE ADVISED (in.)	PROPER LOAD FOR DIFFERENT GRADES OF WIRE (lb.)				
			Patent Steel	Plow Steel	Special Steel	Crucible Cast Steel	Swedish Iron
$\frac{3}{8}$	0.22	12	2800	2620	2200	2000	1000
$\frac{7}{16}$	0.30	15	4000	3540	3000	2720	1360
$\frac{1}{2}$	0.39	18	5500	4560	3800	3520	1760
$\frac{9}{16}$	0.50	21	6000	5800	4600	4400	2200
$\frac{5}{8}$	0.62	27	8000	7200	5700	5420	2720
$\frac{3}{4}$	0.89	36	12000	10000	8200	7760	3980
$\frac{7}{8}$	1.20	42	14400	13600	11000	10400	5200
1	1.58	48	20000	17600	14000	13600	6800
$1\frac{1}{8}$	2.00	54	25200	22400	17000	16800	8400
$1\frac{1}{4}$	2.45	60	30400	26800	21200	20000	10000
$1\frac{3}{8}$	3.00	66	38000	32800	25600	24800	12400
$1\frac{1}{2}$	3.55	69	46000	38400	29200	28800	14400
2	6.30	96	80000	66000	52000	49600	24800

Wire rope should not be run over too small sheaves, for these tend to break the strands and increase materially the wear on the rope. It wears out faster when run at great speed, and therefore should be replaced more often when the speed is high.

Deterioration in wire rope is more often caused by rust than by the wear of constant use. To preserve it properly it should be kept well lubricated with a proper lubricant—one which will penetrate between the wires, prevent friction between them, and cover them so as to prevent corrosion from moisture.

Use of Galvanized Rope. Sometimes as a preventive against rust, the rope is made up of galvanized wires, but this kind of rope should never be used for running ropes—that is, for ropes that pass through pulleys and blocks—as the coating of zinc wears off very quickly, after which the rope rusts with great rapidity. It has also been discovered that in the process of galvanizing, the steel in the wire is likely to be burned, which materially weakens the rope. It is better to keep the rope saturated with a good lubricant.

Kinds and Strength of Wire Rope. The different materials commonly used in the construction of wire rope are patent, plow, special, crucible cast steel, and Swedish iron. Table III gives the proper working loads on hoisting wire ropes of various kinds, and Table IV the safe loads on standing wire ropes.

TABLE IV
Specifications for 6 x 7 Hemp-Center Wire Standing Rope

DIAMETER OF ROPE (in.)	AVERAGE WEIGHT PER FOOT (lb.)	PROPER LOAD FOR DIFFERENT GRADES OF WIRE (lb.)				
		Patent Steel	Plow Steel	Special Steel	Crucible Cast Steel	Swedish Iron
$\frac{3}{8}$	0.22	2700	2540	2100	1920	960
$\frac{7}{16}$	0.30	3600	3420	2800	2640	1320
$\frac{1}{2}$	0.39	4600	4400	3600	3360	1620
$\frac{9}{16}$	0.50	5800	5600	4400	4240	2120
$\frac{5}{8}$	0.62	7000	6800	5800	5280	2640
$\frac{11}{16}$	0.75	8600	8400	6600	6320	3160
$\frac{3}{4}$	0.89	9900	9600	8400	7440	3720
$\frac{7}{8}$	1.20	13000	12800	11200	9600	4800
1	1.58	17000	16800	14000	12800	6400
$\frac{1}{2}$	2.00	22000	21200	17200	16000	8000
$\frac{1}{2}$	2.45	26000	25600	21600	19200	9600
$\frac{1}{2}$	3.00	32000	31200	25200	23200	11600
$1\frac{1}{2}$	3.55	37000	36400	29200	27200	13600

Splices. Wire rope can be spliced so as to make the splice imperceptible. The diameter will not be altered nor the strength materially decreased. A smoother and better splice can be made in wire rope than in Manila rope. The splices for running rope are all of the kind known as the long splice, and should be at least twenty feet in length.

Kinks. Wire rope should never be coiled like hemp rope; it should always be kept on a reel or a drum of some sort. When not on a reel it should be rolled on the ground like a wheel or a hoop to prevent kinking or twisting. Great care should be exercised to see that wire rope is never kinked as this breaks the wire and so destroys the strength of the rope. Kinking, while not uncommon, is a consequence of carelessness and rush work, and can be easily avoided by a little watchfulness.

Engines, Power, Etc.

Kinds of Power. Steam and electric power are used most often in the erection of steel structures; gasoline and compressed air are rarely used.

Size of Engine. To determine the size of a steam engine required on a given piece of work, first determine the proper size of the hoisting cable or rope and select an engine that is slightly larger in capacity than the working load to be put on the cable or

rope, "single part". In selecting the size of hoisting rope, divide the load to be lifted by the number of parts of rope used in connection with the blocks. That is, if a $\frac{5}{8}$ -inch patent steel cable designed for a working load of 8,000 pounds is used running through a single and a double block, thus making four parts, the load to be picked up should not be over 32,000 pounds and the engine should be

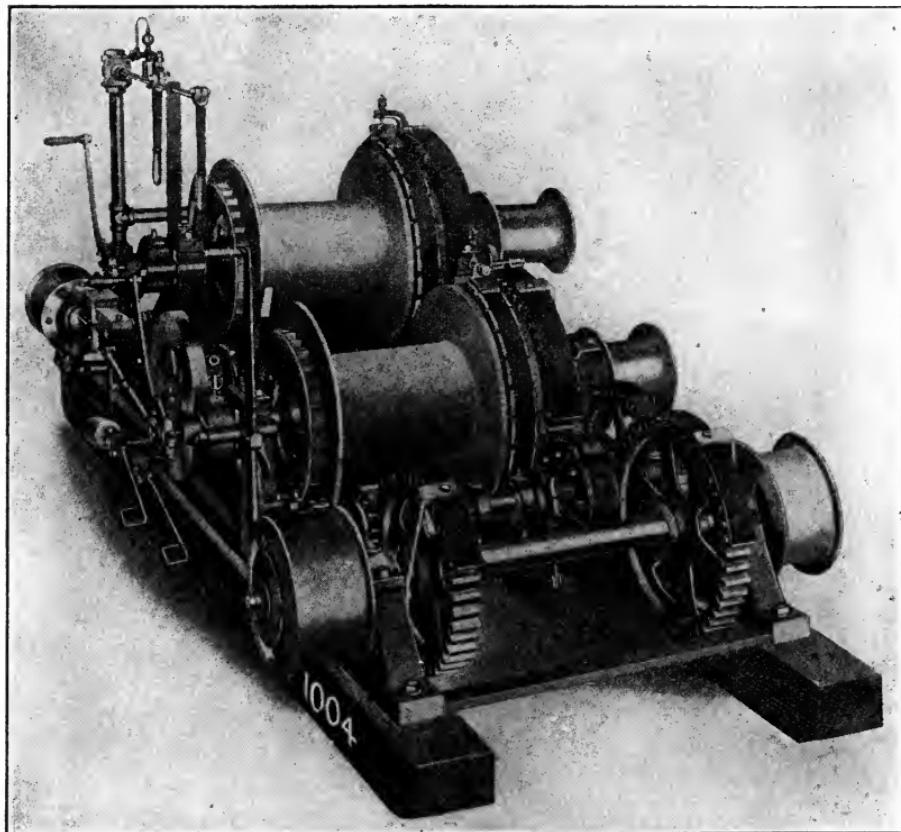


Fig. 20. Steam Hoist Adapted to Building Construction
Courtesy of Lidgerwood Manufacturing Company, New York City

of a capacity to pull at normal speeds about 8,500 or 9,000 pounds on a single line. This means that a steam hoisting engine with two 9- by 12-inch cylinders, commonly rated as a 40-horsepower engine, will be required. If the 40-horsepower engine and $\frac{5}{8}$ -inch cable be used in connection with two double blocks, thus making five parts, a load of 40,000 pounds can be lifted; if used in connection with a double and a triple block, thus making six parts, a load of

48,000 pounds can be picked up; and finally, with two triple blocks, thus making seven parts, a load of 56,000 pounds can be lifted.

Type of Engine. The hoisting engines most commonly found on a steel-setting job are made with two hoisting drums—one to operate the topping lift of the derrick and the other to operate the fall that picks up the load—together with a reversible drum to operate the boom-swinging mechanism on the derrick. These drums are connected to the engine through strong frictions, also held by powerful brakes. This arrangement allows one drum to

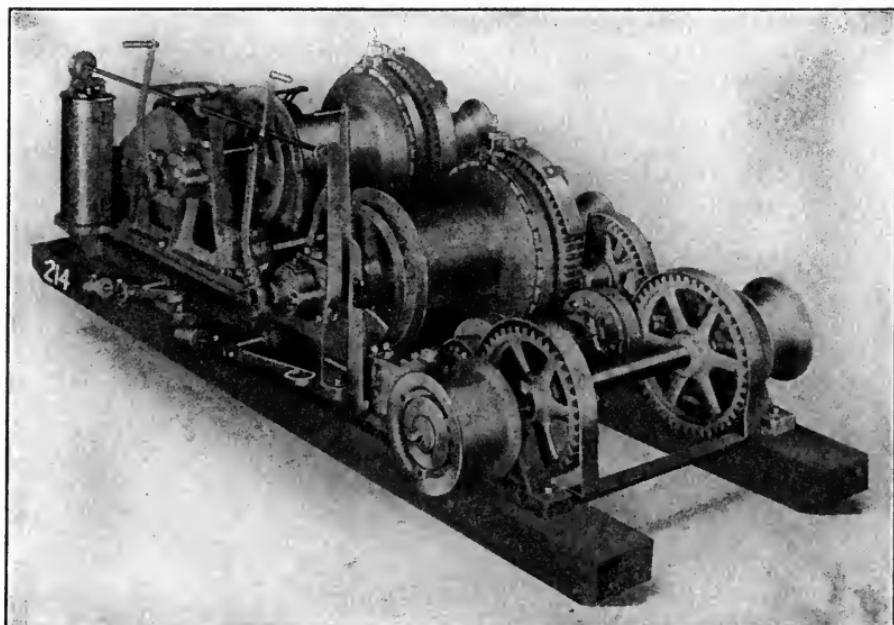


Fig. 21. Electrically Operated Builders' Hoist
Courtesy of Lidgerwood Manufacturing Company, New York City

be used while the other is idle or holding the load, and vice versa. A standard type of steam hoist is shown in Fig. 20.

Steam vs. Electric Hoists. The distinction between a steam and an electric hoisting engine is that of the kind of power used in operating the drums. In choosing an electric hoist to do the same work as a steam hoist, the motor selected should have a capacity at least 50 per cent greater than that of the steam engine. This is because of the different natures of the power. In the steam engine, the power is primarily produced by the expansive energy

in the steam, while in the electric engine, the current energy is exerted to revolve an armature. The faster any engine moves, other conditions remaining the same, the more power it exerts. With a steam engine it is possible to reduce the speed of the drum, although increasing the pressure of the steam, and yet exert the same amount of power as would be exerted if the engine were running at a higher speed but with less pressure. The faster the armature in a motor moves, other conditions remaining the same, the more power the motor produces. It will be easily seen that in setting steel, the speed of the hoist must be varied from slow to fast, and vice versa. The speed of the steam engine is regulated by the amount of steam that is let into the cylinders, while the speed of the electric motor is regulated by means of a resistance box which takes more or less of the energy in the current away from the motor itself. The greater the current that is sent through the resistance coils, the more slowly the hoist moves but also the less power it exerts. It is to overcome this loss of power in the slow speeds that larger-sized motors are required. The same effect is sometimes obtained by using interpole motors and special controllers by which the torque of the armature can be increased about 50 per cent at slow speeds.

Advantages of Electric Hoists. There are several advantages which the electric hoist has over the steam, which offset the disadvantage mentioned above. Some of these advantages are as follows: The electric hoist consumes nothing when it is idle; the cost of maintenance is less; it is ready to start at any time; there is no freezing of water in the winter time; there is no delay of work to raise steam; there is much less danger of fire and none from explosions; it makes no smoke, a great advantage in work where the smoke would injure the finished work. An electric hoist is shown in Fig. 21.

Hand Powers. Where speed is not essential, and on small jobs where the expense of setting up a hoisting engine is relatively large, hand powers, sometimes called crabs, and hand-operated winches are used. These are implements made in a great variety of shapes, sizes, and capacities, which increase the lifting capacity of a man or of several men by means of a system of gears operated by winch handles. They can be bought from implement houses out of stock, with lifting capacities on single line up to 10,000 pounds;

but, of course, the greater the load which these machines pick up, the slower the speed of the cable.

Loads. It is a good practice often of use in the rush of the work, for the superintendent to fix in his mind how much steel it takes to make a ton. He should have mental "short cuts" and practice them so that he can, by looking at a load being lifted, tell very closely how much it weighs. It is easy to remember the following rough estimates of what constitutes a ton: a little over 4 cubic feet of steel; 80 lineal feet, or five 10-inch I-beams 16 feet long, and 60 lineal feet, or four light 12-inch I-beams 15 feet long.

Tackle Blocks, Shackles, Hooks, and Wire-Rope Fastenings. Everyone of these items should be carefully designed and considered for strength, quality, and condition. As stated before, all the preparation for a strong derrick, a strong engine, and a strong rope is of little avail or of no avail if any one of the small details—a block, a shackle, a hook, or one of the fastenings—is not strong enough to carry the load that the large things carry.

Cheap blocks, cheap shackles, and cheap hooks should never be used. They are false economy, especially in these days when the responsibility for accidents, so often causing loss of life, falls upon the owners of the defective machinery. Great care should be taken to purchase only the best of all these small parts.

Tackle blocks used by steel setters should be made of steel. They should have sheaves of a diameter large enough to prevent undue wear of the cable or rope. The pins of the sheaves should be of size sufficient to carry the load and should be fitted with self-lubricating bronze bushings. These blocks should have straps as well as shackles and hooks of strength ample to sustain the load without breaking; especially should the swivel hook on a block be considered, as this one part is often the weakest point of the whole rig. All of the other small items should be gone over and the details carefully considered, with the object of seeing that they are strong enough to perform as much work as the balance of the rig, if not more.

Lines and Levels and How to Establish Them

Importance of Correct Location. The establishment of the lines and levels of a structure is one of the most important phases of the work. The superintendent is not often called upon to do

the work of first locating these lines and levels, but he should always carefully check the locations after they have been established by other parties. Steel structures are generally built upon land that is comparatively valuable, where the owner must cover his entire lot, but where encroachment on his next-door neighbor's property may occasion great loss of time and money. It is therefore a vital matter that the utmost caution be exercised in the location of the structure. There have been cases where the owner of a building has lost his entire fortune through the erecting of a portion of his building on another person's property.

Employment of Licensed Surveyor. It is often expensive to correct a mistake in location unless the error is discovered early. To insure the owner against loss incurred thereby, it is customary for him to employ a licensed surveyor to establish the lot lines and principal levels. The surveyor can be held accountable for his mistakes and be made to pay for the expense of their correction.

Superintendent's Check on Lines and Levels. After the marks have been placed convenient for reference, and after the surveyor has provided the contractor with a plat showing where these marks are to be found, the contractor locates the intermediate lines and levels. It is the superintendent's duty to check all of the measurements, lines, and levels which the contractor has made, with the marks that are placed by the surveyor and also with the drawings, to see that no mistake has been made.

In establishing and in checking lines and levels, both the contractor and the superintendent should use a surveyor's transit and a surveyor's level, both of which should be of first-class workmanship. It is a risk to do this work with anything but accurate instruments. The transit should be frequently tested for vertical alignment, as many sights must be made with the telescope pointing up or down.

Preserving Marks. The most important lines to mark are the boundary lines of the property. These should be permanently marked in places which are not likely to be disturbed during the building operations. There are various ways of preserving these marks: they can be cut into adjacent buildings by means of a cold chisel, or upon sidewalks, curbs, street-car tracks, or other convenient places; they may also be preserved by means of iron stakes,

wooden pegs, or batter boards. All interior lines should be established with reference to the boundary lines.

Locating Foundations. An experienced contractor exercises great care in locating the foundations accurately, both as to height and horizontal location. He knows that the more accurate the work is here, the less trouble and expense he will have in setting the steel above. In a tall building, the other parts of the work, such as walls, partitions, elevators, and stairs, are all placed with reference to the steel skeleton. Therefore, if the steel skeleton is not properly

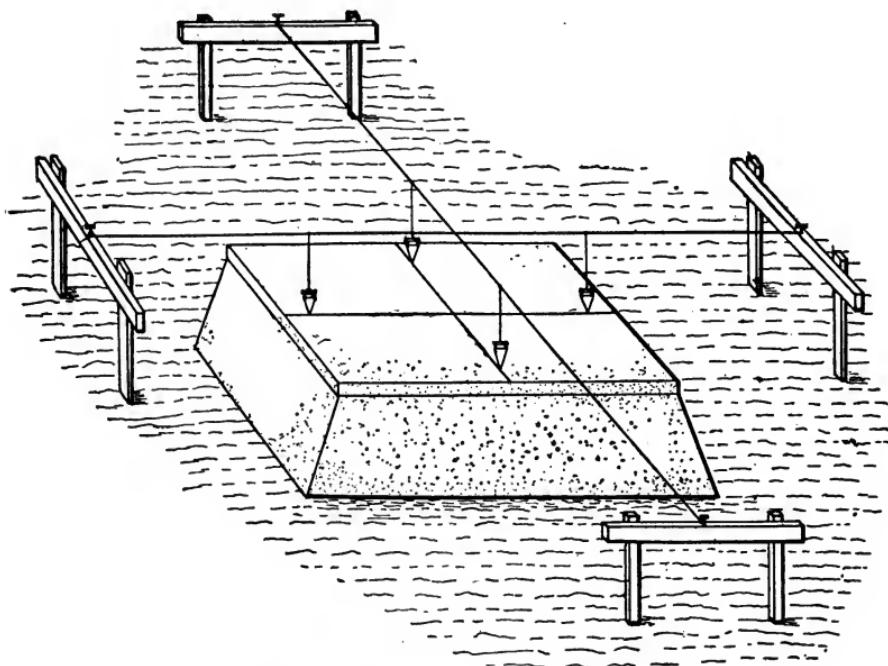


Fig. 22. Layout for Locating Marks in Setting Foundation Shoes

located, much trouble is experienced in making not only the steel but the other parts of the work fit together properly.

Setting Foundation Shoes. On top of the foundation are generally set shoes of some kind on which the columns rest directly. If these are accurately placed, it is reasonable to suppose that the balance of the structure will be properly located. They are of two general types—those that are secured in place by means of anchor bolts into the masonry below, and those which rest directly upon the masonry, being held in place by their own weight and by

the cement grout poured in between the masonry and the bottom of the shoes.

The following is a good method of setting foundation shoes. By means of a transit, points intersecting the center lines of each foundation are marked on the four sides of the foundation, and close to it. These marks are located on batter boards, or something stable, about one foot above the top of the shoe, Fig. 22. From these points are stretched and securely fastened, cords or mason's lines indicating the center lines of the foundation in both directions parallel to the edges of the shoes. In the meantime, the corresponding center lines are marked on the top of the shoe. If anchor bolts are being located, a wooden template is made with holes in it for the bolts and the center lines marked on the template instead of on the shoe. Then the shoe, or template, is moved from side to side until the center lines marked on either are exactly under the center lines marked by the cords, this condition being determined by the use of one or more plumb bobs dropped from the cords.

Setting Shoe at Proper Height. The shoe is set at its proper height by the following method: A wooden stake is driven as close as can be to each foundation in a place where it will not be disturbed, and by means of a surveyor's level the top of the stake is set at the level which the top or, if more convenient, the bottom of the shoe, is to have. When the masonry foundation or the steel grillage below the shoe is built, it will be left with its top one or two inches below the bottom of the shoe in its permanent position.

Anchor bolts, if used, are first located, by means of a straight-edge and hand level, at the right height with reference to the above-mentioned stake. In the same way—that is, by means of the straightedge, hand level, and stake—two thin narrow strips of wood or steel are located and bedded in mortar on top of the masonry, so that the tops of the strips are level and at the elevation of the bottom of the shoe. After the mortar holding the strips has hardened the shoe is placed on them and requires no additional leveling. This method saves much time and patience because, while it is comparatively easy to locate the shoe either horizontally or vertically, it is more often difficult to locate it in both directions at the same time.

Where the strips are objectionable, four steel wedges may be

used, one under each corner of the shoe to raise or lower it to its right location, but this method is not so satisfactory as the use of the strips. The top of the shoe must in all cases be turned or accurately milled in a lathe and be set absolutely level. If not, the column above will rest unevenly on the shoe, thus putting strains on the shoe that may cripple it.

Locating Grillage Beams. When grillage beams are to be placed, the method just described may be followed in locating them. Grillage beams are usually fastened together with separators and bolts. Unless the beams are very heavy, it is well to fasten them together before placing them in their permanent positions.

Grouting Shoes. After the grillage beams and shoes have been properly located and the location checked by the superintendent, strong rich cement grout should be forced into all of the spaces between the beams, shoes, and masonry, so as to make a solid, homogeneous foundation. Care should be exercised to see that no load is placed upon the shoe until after this grout is fully set.

Foundations

The determination of the kind of foundation best suited and most economical for any job is so largely a matter of good judgment and experience that only a few general suggestions are offered as guides in solving the problems as they arise.

Soil. Examination. The superintendent is called upon not only to see that the foundation design is carefully carried out and the workmanship and materials of proper quality, but also to examine the soil or other material on which the foundations are to be built, and to determine correctly whether or not this soil or other material has sufficient bearing power to carry the load to be placed upon it by the foundations as designed. The designing engineer's information concerning the nature and character of the materials lying below the surface at the site of the building, may have been sufficient neither in amount nor in accuracy to enable him to make a design adequate to the work. Test borings may be made, but these are very often unsatisfactory, and only when the foundation hole has been opened so as to allow a close inspection of the material can accurate knowledge of the soil be obtained.

Bearing Capacity. Natural materials vary greatly in their ability to sustain loads placed upon them. These materials range

from quicksand, marshy ground, mud, dry sand, gravel, clayey soils, shale, and rotten rock, to hard, compact rock in its natural bed.

After the soil has been exposed, the first thing to determine is its bearing power. It may be that from past experience and past tests of materials similar to that under consideration the safe bearing power can be correctly decided upon without further investigation. If any doubt should exist regarding it, however, especially where the loads of the structure are to be great, accurate tests should be made. These tests can be made by placing a box about two feet square on the material to be tested, and loading it until settlement is observed, keeping a record of the loads placed and the corresponding settlements.

In common practice it is considered that ordinary soils safely sustain loads from 2 to 4 tons per square foot without settlement; that soft and treacherous soils carry not over 1 ton per square foot, probably less; while for rock, loads up to 50 tons per square foot may be imposed with safety.

Clay. Clay is one of the most deceptive materials upon which to build. When dry, it is firm and reasonably strong, but when wet it becomes elastic and unreliable. It has a great tendency to mix with water. Sometimes it is found combined with sand or with marl, a mixture which when wet is especially treacherous. If the foundation is built on clay, great care should be used to see that good drainage is secured, both before and after it is completed. The effect of frost on clay is very great, and all foundations on it should be started well below the frost line.

Sand. Sand forms an excellent material on which to build so long as it can be kept from shifting. It has, however, no cohesion and has the fluidity of water when water is added to it. Therefore it is of great importance that sand be well drained both before and after the work is begun.

Wet Materials. The construction of foundations in quicksand, under water, and on compressible soils is one of the most difficult with which the engineer and contractor have to contend. Such soils are likely to cause a great deal of trouble, anxiety, and expense, and it requires the greatest skill on the part of the engineer to design the foundations and all of the resources and ingenuity of the contractor to build them. There are many and various

methods employed in the construction of foundations on materials of this sort, comprising cribs, cofferdams, hollow cylinders, caissons, piles, freezing, and others.

Types of Foundations. There are three general types of foundations in common use—surface, sometimes called spread and also floating foundations; pile foundations, either of wood or concrete; and caisson foundations, which are columns of concrete or other masonry carried down through the soft upper strata of materials to the solid rock or hard pan located some distance below. In digging the caisson, two methods are used, one called the open, and the other, in which compressed air is required to keep out the soft material, called the pneumatic process. In some places, notably Chicago, round holes or open wells are sunk through the upper materials to solid rock without the use of air, the holes being filled with concrete.

The bearing power of the foundation material determines the type of foundation to be adopted. Where the material has high bearing power and will not be disturbed, the surface foundation may be the better one to use. Where the soil has little bearing power, pile or caisson foundations may be the cheaper. In some cases where the structure is an important one, the best foundations that can be built will be decided upon, regardless of cost.

Proper Location. In all types of foundations, excepting of course where the columns come directly on top of the solid rock, it is of great importance that the column be located in the center of the artificial foundation, or, where this cannot be done, that the load should be equalized by means of cantilever girders or some similar method.

The superintendent should be alert to detect any attempt made by the contractor or his men to conceal mistakes made in the location of foundations. This is sometimes done by covering the lower portions with dirt, which hide the fact that the top layer, although itself in the right location to receive the column footing, is off the center of the foundation below. It is human nature to try to save the expense involved in the correction of such errors, but sometimes by doing so a dangerous condition is incurred. The writer once heard of a case where a concrete caisson, carried down one hundred feet to rock, was located in the wrong place and this

was not discovered until after most of the basement columns were in place. Thinking to avoid the loss of time and to save the several thousand dollars which correction would have involved, the contractor had the top of the caisson secretly removed and a new top placed in the right location for the whole caisson, thus making the center of the column come on the outer edge of the caisson below. Fortunately this condition was discovered in time, or else a serious accident, perhaps involving loss of life, might have occurred.

The case just cited is an extreme one, but it serves to illustrate what some men do when tempted. It also shows that the superintendent of this building was negligent in his duty, or ignorant of his business; otherwise he would have detected the mistake before the contractor had had an opportunity to yield to the temptation.

Importance of Foundations. The stability and endurance of any structure depend largely upon the character of its foundations. The superintendent should realize that it is of the utmost importance that he give this part of the work special attention. He should see that all the requirements of the specifications and all instructions issued by the engineer or architect are faithfully carried out, and he should report without delay to his superior any probable source of failure he may detect. Besides the quality of workmanship and materials in the artificial foundations, there are two things which are sources of failure and which must be guarded against—inequality of settlement, and lateral escape of the supporting material.

Concrete and Other Masonry. Nowadays concrete enters largely into all foundation work chiefly because of its cheapness and adaptability. The inspection and superintendence of it is like that of any other kind of concrete and masonry work. It is a study in itself and is not to be dwelt upon here.

The most important things that the inspector is called upon to watch are the quality of the materials, the proportion of the ingredients, the thoroughness of the mix, and the method of placing, so that a compact and homogeneous mass is produced. The cement should be properly tested. In the best practice, it comes to the job with the test tags attached to the bags, and there should be at least one test tag to every ten barrels delivered. The superintendent should satisfy himself either by means of the tags or by

some other equally accurate method, that all the cement has satisfactorily passed the inspection. Sand should be clean and sharp. The crushed rock or the gravel should be clean and of good quality. The water used in the mix should be clean and free from all grease or acid; the mixing should be thoroughly done by some good mechanical mixer so that all ingredients are well mingled. Care should be taken that the right amount of cement is used. Cement is the most expensive ingredient, so that the temptation is to put in a smaller quantity than is called for by the specifications; and because of its nature, it is harder to detect a shortage of it than of the other elements in the mixed concrete. Concrete should be thoroughly rammed in place; it should not be so dry as to prevent its flowing into all parts of the foundation. Usually, the specifications covering the work describe fully the proportion and quality of the materials and the method of mixing and placing. The inspector has little difficulty in seeing that a good job of concrete work is done, if he carefully studies these specifications.

Foundation Steel. In all the different types of foundations used for steel structures, steel of some shape and design is generally to be found.

The common practice among engineers is to bed this foundation steel in concrete without painting it, knowing as they do that cement is one of the best preservatives of steel. When steel is so buried, care should be exercised to see that it is cleaned of all dirt, mud, loose rust, and especially loose scale; in other words, prepared so that nothing comes between the steel and the concrete. To preserve the steel, the cement must touch it; therefore, the concrete should be so rammed and spaded that all parts of the steel are thoroughly covered by the cement.

Pile Foundations. Where pile foundations are used, the inspector needs only to follow the engineer's specifications governing the work, using common sense and good judgment in the application of them. He should always be on the job and watch with his own eyes the progress of the work. He should never take for granted that the work is being done properly. If the piles are of wood, the inspector is required to see that each is straight, sound, and of the required length. If the piles are of concrete, the inspector sees that the core is driven to a proper depth; that the core does not

collapse below the surface before the concrete is placed; that the concrete is properly proportioned and mixed; and, as stated before, that all the piles are driven in the right location.

Caissons. Caisson work is a specialty in itself and the contractors undertaking it are nearly always experienced and equipped with especial knowledge as to methods and procedure. The inspection of it consists chiefly in seeing that the caisson is plumb, in passing upon and accepting the bottom when this is reached, and in ascertaining whether or not the concrete or other masonry is properly proportioned, mixed, and placed.

Caisson work is almost always carried on continuously, twenty-four hours a day. This must be done when soft material is encountered, for otherwise the caisson would be inclined to fill during the idle hours. The superintendent or inspector should hold himself in readiness at all times of the day or night to inspect and pass on the bottoms, when notified by the men that these are ready. It is generally dangerous to leave a caisson standing idle long; it is also expensive to keep it clean and ready for concrete for any length of time.

Settlement of Adjacent Structures. One important duty to be performed by the superintendent where the caissons are being sunk near other structures liable to injury by settlement, is to see that no voids are left outside of the caisson shell or lagging. The men are likely to become careless in this respect, particularly where the work is rushed. Such neglect is one of the principal causes of settlement in surrounding structures; it can readily be seen that if the soil has nothing to hold or support it, it will be squeezed out of place by any heavy weight and will move until it encounters something that stops it. Movement causes settlement and this is a dangerous thing. The squeezing of water out of the soil also leads to the same result. It is sometimes practically impossible to prevent some settlement, in which case the safe and the customary thing to do is to shore up the adjacent or adjoining structure, placing it upon jackscrews so that, as the foundations settle, the superstructure can be held to its proper level. Shoring work is in itself a special trade, and all such work should be given into the hands of an experienced shorer or house mover, so that it will be properly and safely handled.

Erection of Superstructure

Standard Erection Specifications. After the foundations are in place, and the derricks, hoisting engines, and other parts of the erection equipment are set up ready for work, the steel for the superstructure will commence to arrive.

Covering the erection of the superstructure, we quote from the standard specifications of the United States Navy Department, Bureau of Yards and Docks, which state the matter tersely as follows:

FIELD WORK

Unloading, Storing, and Handling. Material shall be unloaded, stored, and handled in such a manner and with such appliances and care as to prevent the distorting and injuring of the members; material which is injured shall be repaired or replaced, if necessary, as may be required by the officer in charge and at the expense of the contractor.

Erecting. All field connections shall be riveted. The various members forming parts of a completed frame or structure, after being assembled, shall be accurately aligned and adjusted before riveting is begun. All requirements specified for shop work which are applicable shall apply to the field work.

System in Handling Steel. Sequence in Arrival. System in any work means speed and economy, and this is particularly true in the erection of steel. Theoretically, the steel should come to the structure in such sequence and with just enough rapidity so that it can be taken from the car or wagon and placed in its permanent position without rehandling—an ideal arrangement almost never attained. Under no circumstances should any quantity of material be allowed to accumulate at the building site, which cannot be put in place at once. The cost of moving materials, and the consequent delays in getting them out of the way of construction work, in the long run amount to a considerable sum. Then, too, every time the material is handled it is subject to injury, and in some poorly systematized jobs the steel is moved so often that most of the paint is worn off.

Sorting Yard. When the steel comes from any distance to the shop, especially where it has to be shipped in over railroads, the experienced and capable contractor will provide a sorting and storage yard handy to the job. As the steel arrives, it is sorted and stored so that it can be easily picked up in proper sequence, as needed in the erection work.

The storage and sorting yard allows the steel to be shipped some time before it is to be used at the building. Thus shortages are discovered early, and this tends to insure the erection work against delays.

A quantity of steel ready for the work, provided it is not piled in a confused mass, acts as a stimulus to the men, for they usually put forth greater effort if they can see work ahead of them. If the material is coming to the job in an uncertain manner, the men will be inclined to "nurse" their jobs so as to avoid a lay-off and consequent loss of wages while awaiting the arrival of more steel. Then again, the men usually like to vie with each other in the speed of their work, provided things are moving smoothly and the material is coming to them in the right quantities. This spirit of rivalry not only adds zest to the job, but causes it to be finished more quickly. The best men like to work on something that is being handled properly; they like the excitement in the rushed work; they like a foreman who, while treating them fairly, also pushes the work; and, on the other hand, they dislike a job that is poorly handled and one that drags along.

It costs something to operate a storage and sorting yard, but this is often found to be money well spent and a saving in the long run.

Injured Steel. When steel is bent or twisted out of shape through unskilful and careless handling, either during transportation or at the site, it must be carefully straightened and repaired. If any piece is very badly out of shape, the best thing to do is to have it replaced with a new one; if the bend is not serious, however, the piece may be straightened after heating it to a red heat;* after this it should be again heated all over to a red heat and then left to cool slowly. This process is called annealing and is for the purpose of restoring to the steel all of its original strength and of securing homogeneity of the structure of the metal that is supposed to be injured by unequal heating or by the manipulation attending the straightening process.

Steps in Erection Process. Steel structures, as they are designed in these days, are very rapidly erected. In a tall building as many

* Steel and iron are injured and rendered brittle by being worked at any heat less than a red heat.

as four stories have been erected in one week or six working days.

The different steps taken in the erection of a tall building are about as follows: The columns, girders, beams, and all the large pieces are assembled in place by means of the derricks, etc., the pieces being held together by temporary or erection bolts. Usually the steel men use just as few of these bolts as they can, as it takes time to put them in place. A gang of men now follow who put in the small pieces, such as the separators, tie-rods, and short and light pieces of beams, and do other work which can be handled readily without the use of heavy equipment. In the meantime another gang is busy plumbing up the structure by means of guys in which are inserted turnbuckles, and by means of shores or wooden timbers set diagonally between the foot of one column and the top of the next. These shores are tightened by means of either wedges or jackscrews. After the structure has been assembled and plumbed, aligned and adjusted, the riveting is commenced. It is of great importance for the safety of the structure that the riveting be started as early as possible; it should never be farther than four stories behind the derricks.

Temporary Plank Floors. The factory laws in some States require that temporary plank floors covering the entire area of the structure be placed on the steel as fast as it is erected, thus providing a safe place for the workmen and affording protection against the dropping of bolts, rivets, etc., on persons working below.

Plumbing and Alignment. The shores and guys which the plumbing-up gang have placed should be left in position until they are in the way of the masonry or other parts of the work. The riveting should never go ahead of the plumbing-up. Whether or not the structure is plumb is determined by dropping a heavy plumb bob on the end of a long string fastened to a stick secured to the top of the column, the string being three or four inches away from the column. Then with the aid of a pocket rule, the space between the column and the string is measured at different heights of the column; if these distances are found to vary, the column is pulled by means of the guy or pushed by means of the shores until they are the same.

Provided the column foundation shoes have been properly

set to the right level, there is little use of placing the level on the floors after they have been erected because, unless an error has been made in the fabrication of the columns, the floors follow the levels of the shoes. Therefore it is customary to consider a building in proper alignment after it has been made plumb. If the top of the base plates and the ends of the columns have been properly planed or milled off, and if the base plates have been set level, there is little difficulty in making the structure plumb.

Shims. Where careless work has been done, the contractor sometimes tries to use shims in the joints between the successive column sections. If the shims are of such a nature that the column loads are concentrated on a smaller area of the column section than called for by the engineer's design, the superintendent should not allow them to remain. Shimming columns is the easy and quick way of making the structure plumb. If permitted at all, the shim should be made of a tapered plate that will cover the entire bottom or top of the column.

Floor Beams. In a steel building where fireproof arches are to form the floor construction, care should be exercised to see that all floor beams are set parallel. Where both ends of the beams are connected to girders, there will be little difficulty in this unless the shop has fabricated the steel wrong. It is where the ends of the beams rest upon masonry walls that the most care should be taken in making them parallel. If the floor construction is to be of fireproof tile arches, the superintendent should also watch to see that the tie-rods are all in place and their bolts drawn tight.

Small Castings. The superintendent should always see that wall plates are put in place under all beams and girders that rest on masonry. He should also make certain that all cast-iron and other separators are properly placed and that none are omitted. These separators and many other small items are looked upon by the men as of little consequence; however, if the designing engineer had not thought they were necessary, he would not have included them in the plan of the structure, and it is safe to assume that he knows best what should go into it. Moreover, it is not the concern of the erection gang whether these items are needed or not; if the drawings and specifications call for them, it is the business of the men to put them in place.

Field Riveting. Inspection. The inspection of the riveting done in the field is little different from the inspection in the shop, and all of the requirements listed under "Shop Inspection" apply to the field work. No masonry, fireproof arches, or other work which may cover up the rivets should be allowed to proceed until the riveting has been thoroughly inspected and all defective work rectified. A little carelessness in this respect may result in a number

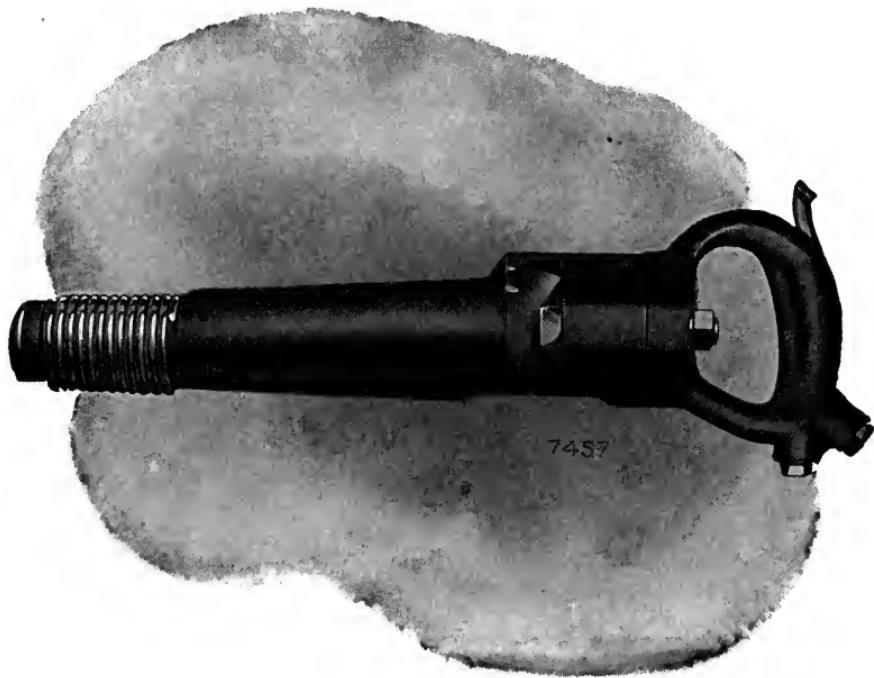


Fig. 23. "Little David" Riveting Hammer
Courtesy of Ingersoll-Rand Company, New York City

of holes being left without rivets and sometimes even without bolts to fill them.

Methods. Because of the difficulty of reaching the places where the rivets go, and because of the conditions surrounding the work, the methods used to drive up the rivets in the field are not so good as those available in the shop. When the erection job is a small one, the rivets are more often driven up by hand. In the better class of work and where the work is of any size, they are driven up by means of pneumatic hammers, Fig. 23, mechanical contrivances actuated by compressed air, which strike many blows

each second. The air compressor, Fig. 24, usually located in the basement or some place where the vibration will not affect the structure, is generally large enough to supply air to several hammers at one time. The air is piped to the hammers, the last length of the pipe being rubber so as to allow the hammer to be moved without delay or trouble.

Necessarily, because of the size of the equipment, the same amount of pressure cannot be brought to bear upon the field rivets as upon the shop rivets, for the shop machines are larger and more

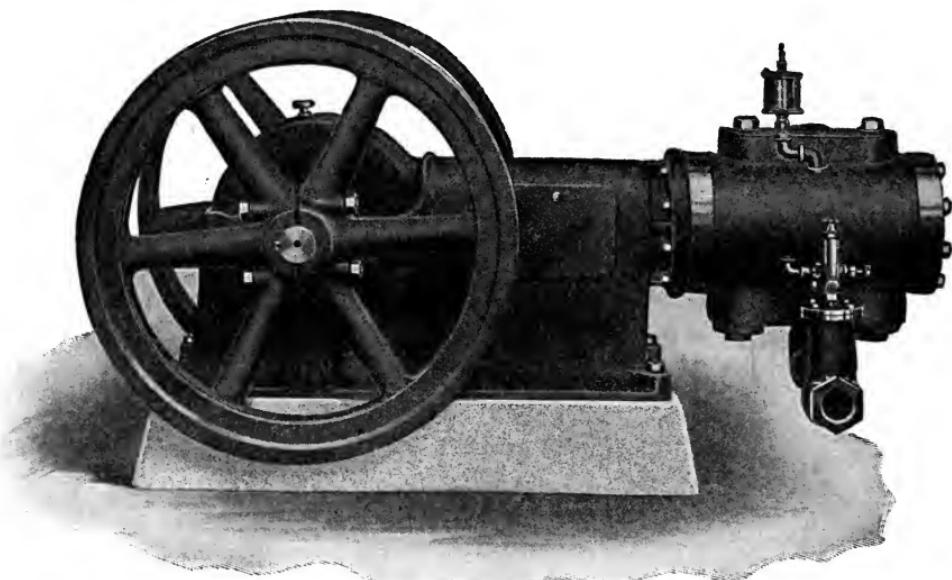


Fig. 24. Self-Oiling Belt-Driven Air Compressor
Courtesy of Blaisdell Machinery Company, Bradford, Pennsylvania

powerful. It cannot be expected, therefore, that as good a job of field riveting can be done as of shop riveting, but there are certain things in the field work that should not be permitted, viz, loose rivets, those with small and badly formed heads, burned rivets, and those which are driven up at a blue heat, that is, a heat ranging from 430 to 600 degrees.

In the field work the noles are not likely to come together so well as do the holes in the shop, and a certain amount of drifting by the use of the driftpin is permitted. If the holes are very bad, however, so that the driftpin does not readily bring them together,

TABLE V
Data for Plain Rivets of Different Diameters

GRIP OF RIVET (in)	DIAMETER OF SHANK (in.)				
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
	LENGTH OF SHANK (in.)				
$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$
$\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{2}{3}$
1	2	$2\frac{1}{4}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$
$1\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$
$1\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$
$1\frac{3}{4}$	$2\frac{7}{8}$	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{5}{8}$	$3\frac{1}{2}$
2	$3\frac{3}{8}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$
$2\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$	4
$2\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{7}{8}$	4	$4\frac{1}{8}$	$4\frac{1}{4}$
$2\frac{3}{4}$	$3\frac{7}{8}$	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{1}{2}$
3	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{5}{8}$	$4\frac{4}{5}$	$4\frac{7}{8}$
$3\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{3}{8}$
4	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{5}{8}$	$5\frac{3}{4}$	$5\frac{7}{8}$
$4\frac{1}{2}$	$5\frac{7}{8}$	$6\frac{1}{8}$	$6\frac{1}{4}$	$6\frac{3}{8}$	$6\frac{1}{2}$
5	$6\frac{3}{8}$	$6\frac{5}{8}$	$6\frac{3}{4}$	$6\frac{7}{8}$	7

NOTE. The lengths of shanks for countersunk heads will be the lengths given above reduced by from 75 to 100 per cent of the diameter of the shank.

they should be reamed out and a larger-sized rivet used than that called for.

Before any rivets are driven up, the steel plates should be drawn together as tightly as possible by means of the erection bolts.

Sizes of Rivets. The size of a rivet is described by the diameter and length of the shank in even eighths of an inch, when it is cold and before it is driven up. The diameter of a rivet should not be over $\frac{1}{16}$ inch greater after it is driven than it is before it is heated. The rivet should, however, fill the hole completely, and to do this it should be heated all over to a red heat in daylight. It should not fall into the hole but require a slight pressure to force it in.

The height of the head of a snap rivet, which is one with a conical head in contradistinction to a countersunk rivet, should be about two-thirds the diameter of the shank, and the diameter of the head should be from one and one-half to two times the diameter of the shank. The grip of a rivet is the total thickness of the plates or parts of metal through which it is to be driven. Its proper length is determined by adding together the grip, the length of

rivet required to make one head, and $\frac{1}{32}$ inch for each joint between the plates to allow for uneven surfaces which prevent closer contact. To this must be added about 9 per cent of the length to allow for filling the rivet hole, which is usually $\frac{1}{16}$ inch larger than the rivet. In Table V is given the data for plain rivets of various diameters.

Heating Rivets. The heating of rivets should be carefully watched. Those made of iron are not as liable to injury from burning as are those of steel. The rivet should be heated all over to a red heat in the daytime; the men will try to slight the work by heating only the ends on which the head is formed. Any steel and wrought iron is rendered brittle and its strength impaired if it is worked, that is, hammered, etc., while at a blue heat, from 430 to 600 degrees. It will be seen, therefore, that rivets must be driven up quickly after they have been heated to the right temperature and that they must not be hammered too long after they are in the holes. The forge in which they are heated should be placed as close to the rivet hole as is practical.

Loose Rivets. All loose rivets should be cut out and new ones driven into their places. The attempt to make them seem tight by the use of the calking iron or by re-cupping with the hammer should never be allowed. The inspector should examine each with the inspector's hammer. If the place into which the rivet is to be driven is difficult to reach, he should look at the rivets before the staging used by the men is removed. When this is done, however, care must be exercised to see that the rivet is cold to the touch before it is tested or disturbed.

Riveting Gang. A riveting gang is generally composed of four men—the heater, the passer, the bucker-up, and the riveter; the last named drives the rivet and is boss of the gang. When there are a number of gangs there is a boss over all the riveters who reports to the general foreman. There are also boys who carry the cold rivets from the storeroom to the heaters and run other errands.

Bolts. In some places in the structure it is found impossible to drive up rivets properly, and the holes must be filled with bolts. If the connections are not important, that is, if the bolts are not depended upon to carry the load from one piece to the next, ordinary bolts are sufficient. If the joint is an important one, the holes

should be reamed out and bolts should be used which have been accurately turned down in a lathe to a size that will exactly fit the hole and require driving to put into place. In all cases where bolts are used, after the nut has been turned up as far as it will go, the screw end should be riveted cold by hammering it until the threads are deformed. This prevents the nut from working loose, which it is likely to do, especially if there be some vibration in the structure.

Painting

Object of Painting. The primary object in painting steel is to preserve it. All steel and iron absorb more or less oxygen when exposed directly to the air and the surface soon becomes coated with rust, which is the resultant chemical change caused by the oxidizing process. Rust is formed very rapidly; it can be for a time interrupted by painting, but the process goes on slowly even under the paint, which in time will peel off, together with a layer of rust. Rust has the peculiar quality of spreading and extending from a center, if there is the slightest chance for it to do so; a small point of rust on the metal may grow under the surface of the paint. Steel and iron are entirely destroyed in time by the action of oxygen. It is therefore of the greatest importance, especially where the metal is buried so that the paint cannot be renewed from time to time, that the metal be protected from the action of the oxygen, either by keeping out the oxygen or by neutralizing it chemically.

Concrete as Preservative. Lime in any of its forms, or combined with other materials to make cement, seems to neutralize the action of oxygen on iron or steel. When these metals are to be entirely encased with concrete, a slight amount of red rust does not affect the lasting qualities of the metal because the lime counteracts the action of the oxygen. However, no scale or loose rust should be left on the metal when it is buried in the concrete.

Kind of Paint. Paint is supposed to be a waterproof and air-tight covering that keeps out the oxygen. There are many brands on the market which are sold for this purpose. The principal duty of the superintendent or inspector is to satisfy himself that without a doubt the contractor is using the specified brand and quality of paint, and furthermore to see that all rust of any

character and all foreign matter, acid, etc., is removed from the steel just before the paint is applied. The first or priming coat is of course the most important; this coat is, however, seldom applied at the building. Some paints when used for the priming coat seem to aid the oxidizing, producing rust rather than preventing it. These, of course, must be most carefully avoided.

Paint for steel must have the property of expanding and contracting in about the same ratio as the steel itself; otherwise it cracks and leaves the metal exposed to the air.

Inspection of Paint. A good way to determine whether or not the right paint is being used is to make the contractor show his receipted bills for the materials. Most good and reputable manufacturers and dealers of high-grade paints will aid in the detection of substitution. They are usually compelled to do this to protect the reputation of their paint. The manufacturer, when asked, keeps the superintendent informed as to how many square feet of surface the paint should cover and also what quantities of paint are being purchased for the particular job in question. With this information, together with the amount of surface that is being covered at the job, the superintendent can soon tell whether or not the right paint is being used. This method cannot always be depended upon, however, and when any doubt exists, other methods of detection should be used. A chemical analyst will sometimes aid in this. Any chemist will also tell the superintendent of some rough test which the superintendent can himself make, such as the burning of lead paints, and what the results will be for pure and impure paint.

In order to see that the required number of coats of paint are given to the work, it is a good plan to have each coat made of a different color or of a different shade of the same color.

MISCELLANEOUS PROBLEMS

Superintendent and Contractors' Organizations

There are many kinds of contracts, and contractors to handle them. Each contractor has his own opinion regarding his organization. An organization varies with the amount of work the contractor executes in a year and also the size of the job or jobs that he has. The small contractor with small work will look after all

the details himself and outside of the few men he actually has to set the steel, will employ no other help whatsoever. He will have his office "in his hat". A concern or an individual contractor handling a medium amount of work has a small organization to assist in carrying out contracts, while a large firm or contractor has a very complete organization to handle all the details of large contracts in the most complete manner possible.

Large Organizations. The large contracting firms have the following general officers: president, vice-president, general manager, chief engineer, superintendent, treasurer, auditor, purchasing agent, and others who have charge of the different parts of the work. Sometimes the duties of more than one of the officers are performed by one person. The work which these officers have to oversee resolves itself into different departments, such as the executive, engineering, contracting, purchasing, auditing and accounting, superintending, storehouse, and transportation departments.

Field Organization. The work in the field will probably be in direct charge of a contractor's superintendent, or if the job is small, of a foreman simply. The contractor's superintendent will have a foreman or several foremen under him, who have charge of certain areas or parts of the work. These men will have as assistants a number of sub-foremen usually called "straw bosses" who are in direct charge of the men.

The theory on which such an organization is based is that any one man has the time and capacity to handle and deal with only a certain number of men. It would manifestly be impossible for one superintendent to direct two thousand workmen doing many different kinds of work, unless he had someone to help him. If he attempted it alone, he would not have time to watch each man, and as a result the men would be inclined to take advantage of him, and not to work when his back was turned. Furthermore, one man could not plan the work so as to keep all the workmen busy and at the same time direct them as to the manner in which the work should be done. The superintendent, however, has time to plan the work, if he has foremen to see that the men do it as he outlines it. In this way, the superintendent has to deal with only a few, instead of directly with a thousand, and he can hold the foremen accountable for the performance of their

duty, while they in turn, have the same control over the sub-foremen, and so on.

In addition to the foremen and the sub-foremen, the superintendent will have one or more timekeepers and material clerks, depending upon the size of the job. When the job is of medium size, one boy can both handle the timekeeping and also order and check up the material as it arrives. On small jobs, both of these things are done by the foreman.

Proper Size of Force. There is always a proper size for the gang any one man should handle. If fewer men than this number are in the gang, the foreman does not have to work as hard as he should and the cost of his salary per man is excessive. If there is more than the required number, then the foreman does not get the maximum amount of work out of them, and loss occurs in that way.

Every organization must be modified to suit the conditions and the work. A very easy and common mistake is to make an organization top heavy with so many foremen and sub-foremen that there is not enough work to go around to keep the different ones busy. This method makes the general expense run beyond that which is economical or possible from the standpoint of cost. A job is properly organized when each man from the head down to the water boy has to work hard and continuously, but not so hard that the work suffers on account of lack of time.

Proper Use of Organization. Early after the contract is let, it is well for the superintendent to inform himself as to the contractor's organization, if he has not already come in contact with it, in order to know who is the proper person with whom to deal in regard to certain matters. Like any tool, the superintendent must know how to use the organization properly.

Superintendent and Superior Officers

Contact with Employer. If the owner is a corporation or other large concern, it will be the duty of the superintendent to find out enough about the organization so that when called upon he will know through what channels to act. Ordinarily, however, if the superintendent is employed by the engineer or the architect, he should take up with his employer all matters that need to go

to the owners and the more important business items in connection with the contractor's work. In all dealings with the owner and with the contractor, the superintendent must ascertain from his superior just how far his duties are to extend, and must act accordingly. The young superintendent oftentimes is overzealous and assumes responsibilities that will cause much trouble to his employer and humiliation for himself.

Necessary Qualities for Superintendent. *Tact.* The superintendent is expected to help his superior in every way he can, and should do so for his own advancement, but it must be real help. He should take up with his superior all matters that may arise outside the routine of his daily work—not trivial things, however, for superiors do not want to be bothered with them. He should also make it a point in some way to keep his boss informed regarding his own actions and rulings, but he must remember that there is a proper time to do this; the man over him has much work to attend to which often cannot be interrupted without causing trouble. On the other hand, the superintendent must not go too far the other way and neglect making proper reports through fear of annoying his superior. In other words, the superintendent must cultivate tact.

Initiative. The more initiative a man has, the more certain is he to advance in his work; but this quality must be directed in the right way.

Webster defines "initiative" as being "an introductory step or move; an originating or beginning". Of course everything must have a beginning, but if too many things are begun at the same time on any one job, confusion results. In any successful work, there must be a system with a head. If the head takes the initiative along certain lines and at the same time his subordinate, without notice to his superior, does the same along other lines which conflict, trouble will surely result. While the superintendent may make plans for the work, he must, before he puts his ideas into action, find out that they do not interfere with other parts of the work and, most important, that they meet with the approval of his employer.

Push. The successful superintendent is always pushing. He keeps his men keyed up, and he is probably of the opinion that

this is one of the most important and most difficult parts of his work. Making people start and finish their tasks on time requires all the diplomacy, tact, and force of which a superintendent may be possessed.

Importance of System

System and Speed. The speed with which buildings and structures are finished depends largely upon system. Every set of mechanics with their materials must be ready to start at the proper time. No department should wait for any other. The architect, engineer, superintendent, contractor, all sub-contractors, and the different mechanics have their certain duties to perform, and all must work hand in hand to accomplish the result. It is just as harmful to the work for the architect or the superintendent to neglect something at the critical time, as it is for the contractor, and sometimes the results are more injurious. The great secret of success in construction work, as in other work, is constant, unremitting "push" in all departments.

Proper Sequence of Work. All persons in construction work soon learn that there are certain times to do certain things, and that, just as in other walks of life, there is a psychological moment in the progress of the work which should be seized to insure success. If these moments are neglected, the chance to do the thing in the shortest and most economical way will be lost forever, and great additional effort, worry, and delay will result.

Many illustrations of the workings of this truth can be given. Suppose that in a tall office building, when the erection derricks reach the eighth floor ready to put in place all the steel of that floor, that for some reason, either because the engineer did not make the design at the right time, or because the shop did not fabricate the piece when it should have done so, one of the large heavy floor girders cannot be put in place. True, the balance of the steel can be erected and the building go on up, but the point is that while the derricks were in place to erect the eighth floor, the girder could have been erected in five minutes' time and at a comparatively small cost. Having to raise it into place afterward will doubtless take hours, perhaps days, and incur many times the original expense, besides interfering with other work and delaying

that which might have been completed if the girder had been erected at the proper time. Furthermore, there is no telling how far-reaching the delay may be.

The writer has in mind another example of the mischief of doing things at the wrong time. The superintendent of a job required that certain supports holding up the forms of a concrete roof of a building nearing completion be taken down too soon. The result was that the entire rear portion of the building crumbled into the basement, and the accident wiped out the owner's entire fortune.

Not only must the superintendent do his own work promptly, but of all men on the job he is the one who should know the very best time for doing each piece of work.

LINCOLN, CALIFORNIA

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